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PATENT-BASED INVESTMENT FUNDS AS AN EMERGING BUSINESS MODEL IN ENTREPRENEURIAL FINANCE

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"I believe that invention is set to become […] a high-value asset that will serve as the foundation for new business models, liquid markets, and investment strategies. […] Create an invention capital market, nurture an invention capital industry, and the resulting virtuous cycle will surely transform the world."

Nathan Myhrvold, Co-founder and CEO of Intellectual Ventures

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List of abbreviations

$	US Dollar
£	British Pound
AUTM	Association of University Technology Managers
BA	Business Angel
B	Billion
CEO	Chief executive officer
CFO	Chief financial officer
CTO	Chief technical officer
e.g.	Exempli gratia (for example)
et al.	Et alii (and others)
etc.	et cetera
i.e.	Id est (that is)
IP	Intellectual property
IPR	Intellectual property rights
IPO	Initial public offering
K	Thousand
M	Million
M&A	Mergers and acquisitions
NPE	Non practicing entity
NVCA	National Venture Capital Association
R&D	Research and development
P	Proposition
p.	Page
p.a.	Per annum
S&P 500	Standard & Poor's 500 (stock market index)
TUM	Technical University of Munich
UK	United Kingdom

US	United States of America
VC	Venture Capital
WIPO	World Intellectual Property Organization

Abstract

Despite the importance of transforming inventions into innovations for stimulating economic growth, many technologies stemming from academic or corporate research remain unexploited. A heterogeneous landscape of players trying to tap into the commercial potential of these unexploited technologies has recently emerged. Patent-based investment funds which actively invest in patents and patentable inventions and try to generate a return from commercialization, are a new phenomenon within this landscape which has only recently found attention in academic research. The aim of this thesis is to enhance our knowledge on patent-based investment funds as an emerging business model in entrepreneurial finance. The research topics covered refer to the activities and commercialization strategies of patent-based investment funds as well as to success factors of IP venturing funds as a sub-group of patent-based investment funds. These topics are explored by means of two essays, both employing a qualitative research approach. Essay 1 draws on the knowledge spillover theory of entrepreneurship and introduces patent-based investment funds as facilitators in the knowledge spillover process. A classification of commercialization strategies is proposed and the relation between these strategies and invention characteristics is examined. Essay 2 draws on agency theory in the context of entrepreneurial finance and develops six propositions on how IP venturing funds can increase returns on commercialization projects through decreasing agency costs and adding value to their portfolio. The results of this thesis contribute to literature on patent and technology intermediaries and new players in entrepreneurial finance. They additionally add to the knowledge spillover theory of entrepreneurship and to theory on the management of agency risk in early-stage investments. Moreover, the thesis has important practical implications for fund managers, managers active in technology commercialization and policy makers.

Keywords: patent-based investment funds; IP venturing; knowledge spillover theory of entrepreneurship; management of agency risk; opportunity recognition

Zusammenfassung

In unserer wissensbasierten Ökonomie nimmt das Thema Technologietransfer eine zentrale Rolle ein. Dennoch bleiben viele Erfindungen aus der Forschung von Universitäten oder Unternehmen ungenutzt. In den letzten Jahren hat sich eine heterogene Landschaft neuer Geschäftsmodelle entwickelt, mit dem Ziel, das kommerzielle Potential dieser ungenutzten Erfindungen zu nutzen. Fonds, die aktiv in Patente und patentierbare Erfindungen investieren und versuchen, durch die Kommerzialisierung der geschützten Technologien eine Rendite zu erwirtschaften, sind ein neues Phänomen innerhalb dieser Landschaft. Forschung zu diesem Thema ist in einer sehr frühen Phase. Das Ziel der vorliegenden Dissertation ist es, das Wissen über Patentfonds als neues Geschäftsmodell im Bereich der Frühphasenfinanzierung zu erweitern. Die Forschungsfragen beziehen sich auf Aktivitäten und Kommerzialisierungsstrategien von Patentfonds, sowie auf die Erfolgsfaktoren von IP venturing Fonds als Untergruppe von Patentfonds. Diese Themen werden anhand von zwei Studien untersucht, welche einem qualitativen Forschungsansatz folgen. Die erste Studie greift die "Knowledge spillover theory of entrepreneurship" auf und definiert Patentfonds als "Enabler" innerhalb des Wissenstransferprozesses. Unterschiedliche Kommerzialisierungsstrategien werden präsentiert mit einem besonderen Fokus auf den Zusammenhang zwischen Kommerzialisierungsstrategien und Technologiecharakteristika. Die zweite Studie baut auf der "Agency" Theorie im Kontext der Frühphasenfinanzierung auf. Sechs Thesen zur Steigerung der Rendite auf Kommerzialisierungsprojekte durch verringerte "Agency" Kosten und Wertsteigerung des Portfolios werden vorgeschlagen. Die Ergebnisse der Dissertation tragen schwerpunktmäßig zur Forschung im Bereich Patent- und Technologieintermediäre sowie neuer Geschäftsmodelle in der Frühphasenfinanzierung von technologiebasierten Neugründungen bei. Zudem erweitern sie Aspekte der "Knowledge spillover theory of entrepreneurship" und der Theorien zum Management hoher Agency Risiken. Die Dissertation hat wichtige praktische Implikationen für Fondmanager, Manager im Bereich Technologietransfer und politische Entscheidungsträger.

Schlagwörter: Patentfonds; IP venturing; knowledge spillover theory of entrepreneurship; Management von "Agency" Risiken; Erkennen von unternehmerischen Möglichkeiten

I. Introduction

1. Motivation, research topics and structure of the thesis

Inventions must be exploited and turned into commercially viable innovations in order to contribute to economic growth. This transition is central in our knowledge-based economy. Weitzman (1998) notes that "the ultimate limits to growth may lie not so much in our ability to generate new ideas, so much as in our ability to process an abundance of potentially new seed ideas into usable form" (p. 333). Inventions stemming from research efforts, for example, by companies and universities spill over to the economy through internal and external commercialization and entrepreneurial activity (Acs and Sanders 2012; Carlsson et al. 2009). Patent rights protect inventions, allow the owner to exclude others from using them, facilitate tradability and ensure the appropriability of returns (Hall and Harhoff 2012; Arora and Gambardella 2010; Chesbrough 2003).

However, there are many impediments to the transfer from invention to innovation, especially in the early stages of commercialization (Festel 2013; Acs et al. 2004; Auerswald and Branscomb 2003). Markets for patents and technologies are highly inefficient, illiquid and opaque (Arora and Gambardella 2010; Troy and Werle 2008; Gambardella et al. 2007; Shane 2003; Arora et al. 2001; Teece 1986) and a financing gap exists in the early stages of technology development (Maia and Claro 2013; Mason and Harrison 2004; Auerswald and Branscomb 2003). A "capital market for inventions" – a term coined by Nathan Myhrvold, the Co-founder and CEO of Intellectual Ventures[1] – is still in its infancy. A sustainable system that facilitates technology transfer by connecting market participants, enabling division of labor and providing funding and at the same time generates returns compensating capital providers for their risk taken is highly desirable.

New business models have recently emerged that try to foster the development of a "capital market for inventions". Myhrvold (2010) notes:

[1] Intellectual Ventures is one of the largest funds aggregating and exploiting patents and patentable inventions. For more information see, for example, Ewing and Feldman (2012) and Krech et al. (2015).

> "What we're really trying to do is create a capital market for inventions akin to the venture capital market that supports start-ups and the private equity market that revitalizes inefficient companies. Our goal is to make applied research a profitable activity that attracts vastly more private investment than it does today so that the number of inventions generated soars." (Myhrvold 2010)

Emerging business models have been researched in the context of technology and patent intermediaries (Krech et al. 2015; Gredel et al. 2012; Wang 2010; Benassi and Di Minin 2009; Chesbrough 2006b; Elton et al. 2002) as well as in the context of new players in entrepreneurial finance (Festel et al. 2015; Bradley et al. 2013; Maia and Claro 2013; Festel and De Cleyn 2013). Moreover, intellectual property rights (IPR) as a stand-alone financial asset have received increasing attention in practice and in academia (Reitzig et al. 2007; Fine and Palmer 2002). Interestingly, fund models that are based on the monetization of pure patent rights are increasingly searching for options to reconnect intellectual property (IP) to the products and processes it supports (Donegan 2015). The potential ability of these business models to reduce impediments in the invention-to-innovation process whilst creating appropriate returns for investors highlights the academic and practical importance of understanding them better. However, research is in a nascent stage and just as scattered as the heterogeneous landscape of players itself.

Patent-based investment funds are a new phenomenon in this landscape of players which has largely been neglected in academic research so far. These funds acquire or gain control over patents or patentable inventions, do not consider R&D or production as a core competence (Krech et al. 2015) and invest privately or publicly raised funds. They aim to generate a return for their investors by commercializing the technology through different pathways and receiving proceeds from royalties, patent sales or sale of equity shares (Gredel et al. 2012). The overall objective of this thesis is to enhance our knowledge of patent-based investment funds as an emerging business model in entrepreneurial finance.

Research exploring patent-based investment funds has so far focused on providing taxonomies of parts of the spectrum of potential commercialization paths. These contributions ana-

lyze how original patent owners can leverage these funds in the context of open innovation and external technology commercialization (e.g., Krech et al. 2015; Benassi and Di Minin 2009). In so doing they often do not differentiate between players solely active in the market for patents and those focusing on technology transfer (Fischer and Henkel 2012). The role of funds within the invention-to-innovation transition therefore remains unclear. Distinct activities and the full spectrum of commercialization strategies have not been researched. In an attempt to address this research gap, this thesis explores the following research topic:

Topic 1: Activities and commercialization strategies of patent-based investment funds

In addition, extant research has so far neglected success factors of patent-based investment funds (e.g., Krech et al. 2015; Festel et al. 2015; Gredel et al. 2012). Investments in the early stage of technology commercialization are characterized by high risk and uncertainty (e.g., Hall et al. 2005; Baum and Silverman 2004; Gompers 1995). Only if funds find ways to manage these risks and add value to their investments so that they generate attractive returns for investors will they be able to reduce the financing gap in the long run and contribute to the development of a sustainable "invention capital market":

> "What will it take for the invention capital market to come into its own? A group of companies […] has to prove the concept. […] And two or three invention funds need to produce great returns." (Myhrvold 2010)

Understanding success factors of these players is not only of high academic relevance but also has important practical implications with respect to the implementation of business models, collaborations between funds and technology producers as well as for an innovation-enhancing policy agenda. Addressing this research gap, the second research topic of this thesis is:

Topic 2: Success factors of IP venturing funds as a sub-group of patent-based investment funds

Having described the overall research topics of this thesis, the next section provides background and an overview of relevant literature streams to motivate the research topics in great-

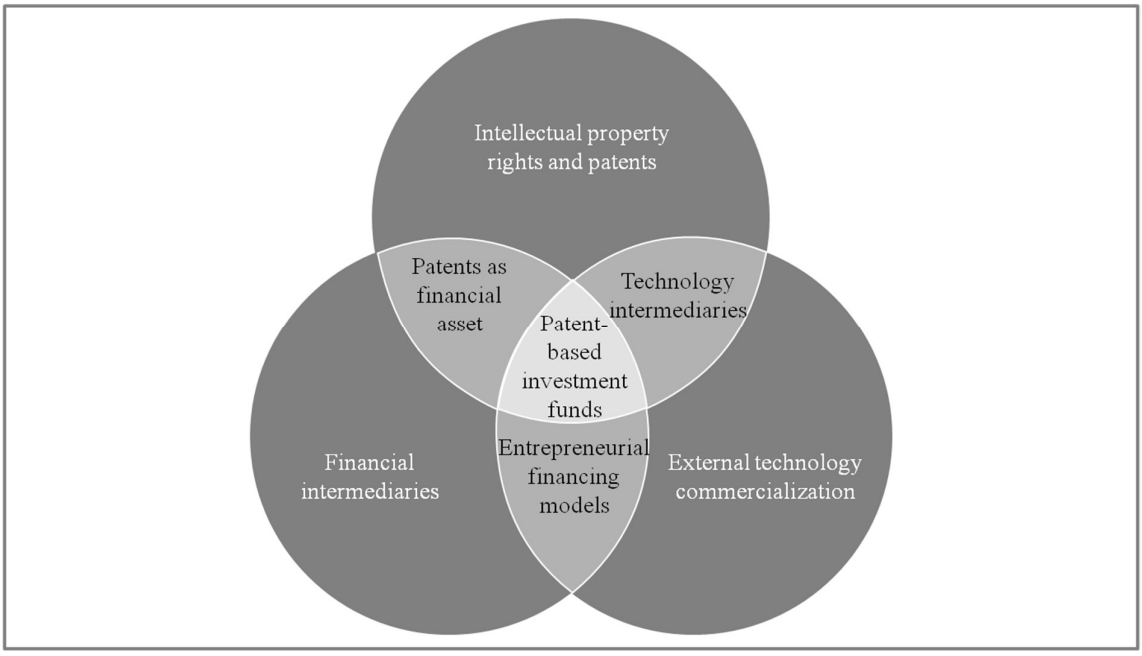
er depth. Subsequently, the research approach is presented and a short introduction to the two essays analyzing the research topics is given. These two essays, "From invention to innovation – patent-based investment funds as facilitators in the knowledge spillover process" and "Businss builders, contractors and entrepreneurs – an exploratory study of IP venturing funds", make up the main body of this dissertation. The last chapter of the thesis summarizes results and theoretical implications, highlights practical implications and concludes with an outlook on future research on patent-based investment funds.

2. Background and literature overview

This section provides the bigger picture for the research topics to underpin the importance of better understanding the new phenomenon of patent-based investment funds. Background is provided by drawing on current developments and an overview of the broader literature streams relevant to the topic is given. Thus the research topics outlined above are embedded in both a practical and a theoretical context. Broader contexts relevant to patent-based investment funds are intellectual property rights and patents, external technology commercialization and financial intermediaries. Nascent research on patent-based investment funds can be located at the intersection of different groups of players in these contexts: technology intermediaries, entrepreneurial financing models and patents as financial assets. Research gaps at this intersection are highlighted and the relevance of researching patent-based investment funds in order to fill these gaps is derived. Relevant research streams and their intersections are illustrated in Figure 1.

Figure 1: Relevant literature streams and research gap

Source: Own illustration



2.1. Overview of broader literature streams

2.1.1. Intellectual property rights and patents

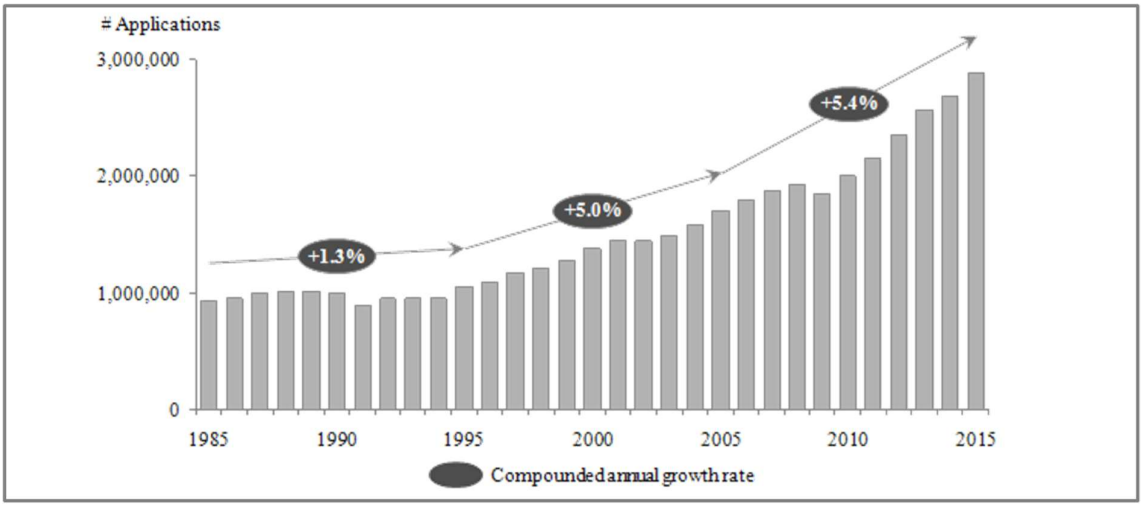
Intellectual property rights protect intellectual assets such as inventions, literary works or images which are non-rival in nature. They include, for example, patents, trademarks, industrial designs and copyrights (WIPO 2016). Thereof, patents are "the most important High Technology IPR" (Pitkethly 2001, p. 426). A patent allows the owner to exclude others from using an invention that is "new, non-obvious and commercially applicable" (WIPO 2016, p. 155), for generally 20 years. Thereby it grants a monopoly for a given time period and allows the inventor to appropriate returns from the invention, which encourages innovation. In exchange, the invention is disclosed to the public (Hall and Harhoff 2012; Chesbrough 2003). The patent system thus aims to balance the tension between private and public gain from research (Gould and Gruben 1996). Moreover, it facilitates tradability because patent rights can be transferred to others (Arora and Gambardella 2010). Empirical evidence supports the argument that IPR protection influences innovation and economic growth (e.g., Block et al. 2013; Acs and Sand-

ers 2012; Gould and Gruben 1996). Therefore "patents have become the most common measure of innovation output" (Giuri et al. 2007, p. 1108).

The importance of intellectual property in our knowledge-based economy is illustrated by the rising number of patent applications and the increasing share of intangible asset value of firms' total market value. Patenting activity has increased significantly over the last two decades. Worldwide patent applications, for example, rose by > 5% p.a. from 1995 to 2015 (Figure 2), demonstrating acceleration in technological development across regions and the important role of patents. In total, 2.9M patents applications were registered worldwide in 2015, thereof 12.5% in Europe and 21.7% in North America; 1.2M patents were granted in 2015 (WIPO 2016). Patenting activity by universities and public research institutions increased significantly in the last decade: their share of total patent families[2] rose from 8.9% in 2005 to 16.4% in 2013 (WIPO 2016). As patenting involves high costs (e.g., patent office fees), small and medium-sized enterprises (SMEs) tend to have a lower propensity to patent (Gredel et al. 2012; Svensson 2007).

Figure 2: Trend in worldwide patent applications

Source: WIPO statistics database. Last updated: February 2017



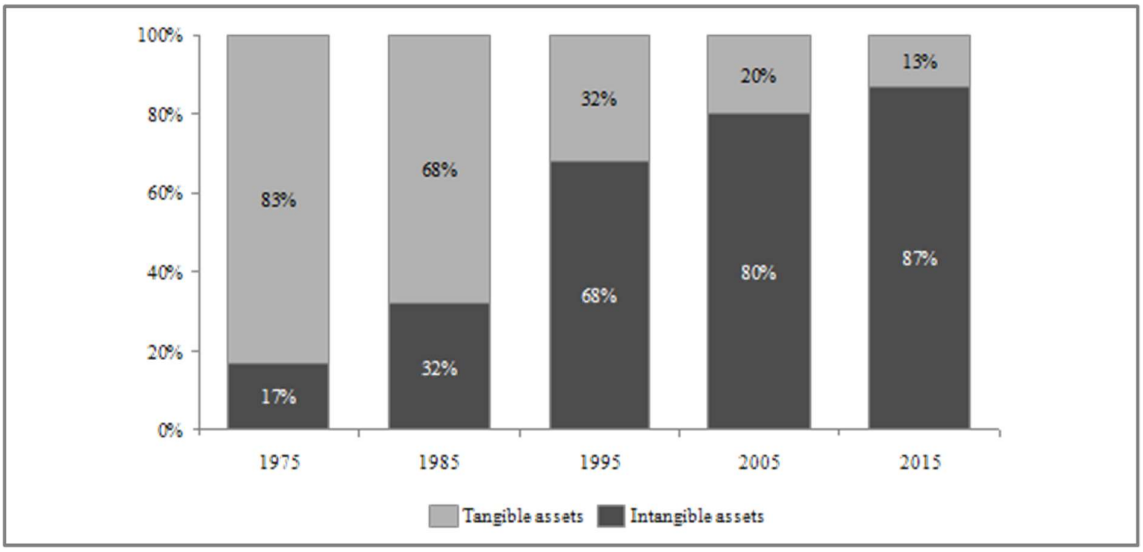
Corresponding to rising patenting activity is an "increased importance of intangible assets relative to tangible assets in today's developed economies" (Hall and Harhoff 2012, p. 18).

[2] Patent families are "patent applications interlinked by one or more of: priority claim, Patent Cooperation Treaty (PCT) national phase entry, continuation, continuation-in-part, internal priority and addition or division"; the measure takes into account that some patents are filed at more than one office worldwide. (WIPO 2016)

According to estimates by Ocean Tomo LLC (2017), a US provider of intellectual property services, intangible assets make up 87% of the S&P 500 market value (Figure 3). These assets include not only formal IPR such as patents or copyrights, but also, for example, trade secrets. However, patented technology represents a significant share of this value (Ocean Tomo LLC 2017).

Figure 3: Components of S&P 500 market value

Source: Ocean Tomo, LLC (2017)



Academic research relevant to this thesis examines the use of patent portfolios as well as challenges of valuing patents and distributions of patent values. Findings have implications for our research topics. First, patent portfolios of both companies and research institutions are often underexploited (Giuri et al. 2007; Elton et al. 2002; Rivette and Kline 2000). Giuri et al. (2007) show that 17.5% of patents are lying idle, i.e., they are neither exploited nor have a strategic value through blocking competitors. For large companies (19.1%), public research institutions (34.1%) and universities (27.5%) the share is even higher (Giuri et al. 2007). Although not all of these patents will have commercial potential, Palomeras (2003) shows that "sleeping patents are more innovative, broader and not less important than their counterparts" (p. 1). This relates especially to inventions that can be applied in unrelated sectors outside a companies' strategic core (Palomeras 2003). It is therefore suggested that significant unused commercial potential lies in such underexploited portfolios (Block et al. 2013; Braunerhjelm

and Svensson 2010; Carlsson et al. 2009), which might be leveraged by patent-based investment funds.

Second, research on patent values shows that they are highly skewed (Gredel et al. 2012; Gambardella et al. 2008; Hall et al. 2005; Scherer 1965). Also, values can change over time and are highly contextual (Gredel et al. 2012). They contain the "right to exclude others from practicing the invention", but also serve as a "proxy for the value of the underlying invention, which may have private value even without the patent right" (Hall and Harhoff 2012, p. 18). With regard to the former component, there is the risk that the legal right can be invalidated. With regard to the latter aspect, the technology may become redundant as it is replaced by a new one (Gredel et al. 2012). On the one hand, these characteristics make valuation difficult and investments risky. On the other hand, returns can theoretically be high. Moreover, "a patent lying on the lower part of the value distribution in hands of the current patent holder could be at the opposite extreme of the distribution if exploited by another firm" (Palomeras 2003, p. 3).

2.1.2. External technology commercialization

Literature on technology commercialization in general deals with the question of how new knowledge is actually transferred into commercially valuable innovations. Whereas patents are often used as proxies for new knowledge (e.g., Block et al. 2013) and intellectual property rights play an important role for the appropriation of returns in the invention-to-innovation process (e.g., Acs and Sanders 2012), the underlying technology, not the legal construct of IPR, is at the centre of interest. Literature on technology commercialization is very broad and spans a variety of academic fields such as economics, entrepreneurship and marketing (Datta et al. 2013).

One research stream crucial for the research topics explored in this thesis deals with the highly complex process from invention to innovation, "by which a technical idea of possible commercial value is converted into one or more commercially successful products" (Auerswald and Branscomb 2003, p. 227). Critical steps in this process include the development

of a technical concept and prototype, the business validation through the definition of a production process as well as quantification of the market, product development and finally production and marketing of the final product (Guerrero and Urbano 2014; Block et al. 2013; Acs and Sanders 2012; Carlsson et al. 2009; Auerswald and Branscomb 2003). This process can take place within the inventing organization. Alternatively, patented technologies can be sold or licensed to other parties through the market for technology (Hall and Harhoff 2012; Arora and Gambardella 2010; Gambardella et al. 2007), or transferred to a new start-up through an academic or corporate spin-off (Festel 2013; Carlsson et al. 2009).

The external commercialization of technology has found increasing attention in the context of open models of innovation (Ziegler et al. 2013; Gassmann 2006; Chesbrough 2006b, 2003). This was triggered by the growing awareness that knowledge – and patents protecting technological inventions – is valuable and should be actively leveraged (Harris, 2001). Shorter technology life cycles (Granstrand 2004; Chesbrough 2003), increased R&D costs (Keupp and Gassmann 2009) and the global competitive dynamic (Gassmann 2006) similarly contributed to this development. Moreover, commercialization of research results through universities and research institutions was encouraged through regulatory changes. In the US, for example, the Bayh-Dole Act of 1980 enabled universities to exploit patents created from federally-funded research (Bradley et al. 2013; Festel 2013; Jensen and Thursby 2001). External patent exploitation can be defined as "an organization's deliberate exploitation of patents to another independent organization with or without know-how transfer involving a contractual obligation for monetary or non-monetary compensation" (Ziegler et al. 2013, p. 933). Commercialization *with* knowledge transfer will be paramount for the research focus of this thesis.

The increased focus on external technology commercialization activities is demonstrated by the fact that firms have started to create dedicated patent management resources (Bianchi et al. 2011; Grindley and Teece 1997). Similarly, many universities in the US established Technology Transfer Offices and entrepreneurship centers to provide support in commercialization activities and foster a more entrepreneurial culture (e.g., Goldfarb and Henrekson 2003; Franklin et al. 2001). Increased exploitation through the market for technology is illustrated by a recent increase in licensing volumes (Granstrand 2004) and the rising value of technolo-

gy transactions (e.g., Arora and Gambardella 2010) which, however, is driven by very few active firms (Alexy et al. 2009). Moreover, the number of university spin-offs has increased considerably in recent years. For example, the Association of University Technology Managers reports for the US that 1,012 new start-ups were formed in 2015, up from only 212 start-ups in 1994 (AUTM 2015).

Several factors exist, however, that still impede external technology commercialization. As a result, a technology transfer gap exists between research and the commercialization of inventions (Festel 2013; Braunerhjelm et al. 2010; Acs et al. 2004). First, inefficiencies in the market for technology make technology transfer through licensing difficult (Arora and Gambardella 2010; Troy and Werle 2008; Gambardella et al. 2007; Shane 2003; Arora et al. 2001; Teece 1986). Markets for technology are lacking transparency regarding both market participants and traded assets. By definition, patents cover new and unique inventions. This implies a high uncertainty regarding the quality of available patents, their value as well as the transaction process and eventually leads to high transaction costs (Rüther 2012; Gans et al. 2008; Troy and Werle 2008; Gambardella et al. 2007). Furthermore, information asymmetries are high as the inventor possesses more information about the invention and often is reluctant to fully disclose findings and know-how (Hall 2008). This is even more pronounced when the technology underlying the patent is in an early development stage (Svensson 2007). Due diligence and valuation are therefore costly and difficult (Hall 2008; Pries and Guild 2007; Svensson 2007). In the case of licensing of very early stage technology, the uncertainty for the licensee is not only high with respect to the newness of the technology itself but also with respect to its readiness for product application (Pries and Guild 2007).

Furthermore, there are impediments to the commercialization of knowledge (both internally and externally) on the organizational and individual level. On the organizational level, regulations and policies can present barriers that do not allow for an open innovation approach (Guerrero and Urbano 2014; Auerswald and Branscomb 2003). This also includes a lack of commercialization resources and capabilities, which prevails especially in small corporations and research institutions (Gredel et al. 2012). On the individual level, attitudes with regard to the desirability and feasibility of entrepreneurial activities, as well as incentives, deter inven-

tors from pushing forward commercialization activities (Guerrero and Urbano 2014; Auerswald and Branscomb 2003).

Last, a financing gap, also referred to as the "valley of death" (Auerswald and Branscomb 2003, p. 229), is observed especially in this early stage of technology development where concepts and prototypes are developed to prove technical feasibility (Maia and Claro 2013; Mason and Harrison 2004; Auerswald and Branscomb 2003). This stage is between the basic research funded by public sources and corporates and the stages of product development and beyond financed by traditional entrepreneurial finance providers such as venture capital (VC). The transfer from invention to "the commercialization of a new product or a new technology can be long and costly" (Giuri et al. 2007, p. 1117) and the associated information asymmetries and uncertainty at this stage deter private investors (Maia and Claro 2013; Mason and Harrison 2004; Auerswald and Branscomb 2003). All of the impediments discussed contribute to the fact that not all inventions are turned into commercially viable innovations and that large shares of patent portfolios are lying idle.

2.1.3. Financial intermediaries

Financial intermediaries act as middlemen between parties in a financial transaction. Information asymmetries and high transaction costs have served as foundation for explaining the existence of financial intermediaries (Allen and Santomero 2001; Bhattacharya and Thakor 1993; Santomero 1984). When information asymmetries with regard to asset quality exist and moral hazard hampers the exchange of information, intermediaries can add value through evaluating assets (Santomero 1984; Leland and Pyle 1977), interpreting signals (Leland and Pyle 1977) and acting as "informed agents in a market with imperfect information" (Chan 1983, p. 1543). Moreover, they offer a diversification potential (Santomero 1984; Chan 1983) and decrease transaction costs (Bhattacharya and Thakor 1993; Santomero 1984). Financial intermediaries increase the value of the portfolio of assets and allow investors to earn a return on their capital through taking a share in this portfolio (Santomero 1984; Leland and Pyle 1977). The intermediary's role includes the management of the relationship with investors, the origination and review of potential investments, the selection and structuring of deals, the

oversight of assets in the portfolio and finally the management of an exit where the return is realized (Gompers and Lerner 2004; Sahlman 1990).

Investments in both early technology commercialization and patents are characterized by extremely high information asymmetries and transaction costs (Hall 2008; Pries and Guild 2007; Baum and Silverman 2004; van Osnabrugge 2000; Sahlman 1990; Gompers 1995). Most of the literature examining financial intermediaries in these contexts deals with traditional players such as venture capital funds. They provide capital to new firms exploiting entrepreneurial opportunities, which most often lack own financial resources and which have difficulties in obtaining bank financing as they lack cash flows and collaterals (Block et al. 2017). At the same time, they allow resource owners to invest in a portfolio of entrepreneurial ventures and to participate in "high-risk, potentially high-reward projects" (Gompers and Lerner 2001, p. 145). With the growing importance of entrepreneurship as a means to transfer invention to innovation (Festel 2013; Block et al. 2013; Denis 2004), capital allocated to the financing of new firms rose and entrepreneurial finance was established as a growing research field (Denis 2004).

Extant research aims at understanding activities of these investors as well as how they decrease information asymmetries and manage associated agency risks (Sahlman 1990). These analyses refer to the selection and contracting activities as well as post-investment services (e.g., Baum and Silverman 2004; Kaplan and Stromberg 2001; Gompers 1995). Moreover, exits and realized returns as well as their determinants at fund and deal level have often been investigated (e.g., Gompers et al. 2009; Cochrane 2005; Long III 1999). Another stream of research focuses on the organizational form, the relationship between general and limited partners and fund raising activities (e.g., Gompers and Lerner 2004; Murray 1999; Sahlman 1990). Research on newly emerging players in the field of technology commercialization and patents has so far largely neglected such issues in the context of financial intermediation.

2.2. Players at the intersection of intellectual property rights, external technology commercialization and financial intermediaries

2.2.1. Technology intermediaries

At the intersection of IPR and and external technology commercialization, literature on technology intermediaries can be located. The increase of knowledge production and patenting activity, as well as the awareness of firms and research institutions for the importance of and impediments to commercializing technology externally have given rise to these players on the market for technology (Chesbrough 2006b). Technology market intermediaries bridge supply and demand for technology and "aim at matching technologies with market applications" (Gredel et al. 2012, p. 538). They moreover aim to decrease market inefficiencies due to their market knowledge, networks with possible transaction partners and valuation and process experience (e.g., Tietze and Herstatt 2010; Benassi and Di Minin 2009). They are therefore important enablers in the era of open innovation (Kamiyama et al. 2006).

The landscape of technology intermediaries is heterogeneous and ranges from agents and market makers to business models actively investing in technology. Patent-based investment funds are considered a sub-group of technology market intermediaries by both academic and non-academic researchers (Krech et al. 2015; Gredel et al. 2012; Rüther 2012). Literature on these players is limited and rather fragmented. Research focuses on exploring different business models and how they can be used by firms to leverage their patent portfolios (Wang 2010; Benassi and Di Minin 2009; Millien and Laurie 2007; Elton et al. 2002). However, typologies often lack a clear differentiation between players in the market for technologies versus players monetizing solely the legal right. Moreover, contributions do not cover some aspects of the financial intermediation literature.

For example, in their review of IP-based business models Millien and Laurie (2007) present intermediaries such as licensing agents or patent brokers from a practitioner standpoint. Wang (2010) introduces patent brokers as "companies that serve a connective and advisory function in linking patent sellers with potential buyers" (Wang 2010, p. 160), but does not differentiate

them further. Benassi and Di Minin (2009) provide a more comprehensive typology of patent brokers that includes intermediaries with varying degrees of value add. These range from consultants and service providers to patent deal makers and aggregators. Only the latter group adds high value and takes risk through investing in the development of patent portfolios (Benassi and Di Minin 2009). Literature on intermediaries commercializing technology through start-up creation is extremely limited. Only Elton et al. (2002) and Millien and Laurie (2007) discuss "business builders" (Elton et al. 2002), technology transfer offices of universities and IP spin-off financing (Millien and Laurie 2007) in the context of technology intermediaries that support start-up creation based on patents and patentable inventions.

2.2.2. New business models in entrepreneurial finance

Literature on business models in entrepreneurial finance can be located at the intersection of literature on external technology commercialization and financial intermediaries. As mentioned above, a financing gap exists in the very early stages of technology commercialization which impedes the transition from invention to innovation (Auerswald and Branscomb 2003). In these early stages, which are also referred to as pre-seed and seed stages, information asymmetries and agency risks are particularly high (e.g., Hall et al. 2005; Baum and Silverman 2004; Gompers 1995). The financing gap deteriorated after the financial crisis in 2008/2009 when bank lending contracted due to regulatory changes (Block et al. 2017; Gompers and Lerner 2004). In addition, traditional financial intermediaries in this field, such as venture capitalists, have moved to later and less risky stages in recent years and are increasingly reluctant to provide funding in the technology sector (Ewens et al. 2015; Mason and Harrison 2004). They therefore cannot fully cover the financing needs of new technology-based firms. At the same time, the low interest environment caused investors to look for alternative investment opportunities (Block et al. 2017).

As a result of this development new business models providing entrepreneurial finance have emerged in order to fill the prevailing equity gap (Block et al. 2017; Ewens et al. 2015). New players have "introduced new investment approaches, valuation methods or measures, and business models of entrepreneurial financing" (Block et al. 2017, p. 2), leading to a more het-

erogeneous and complex landscape of players in entrepreneurial finance. Block et al. (2017) provide an overview of some of the new players. Among them are accelerators and incubators, angel networks, family offices or crowdfunding (Block et al. 2017). Most of these models provide funding for existing start-ups. Entrepreneurial finance models which are active before the foundation of a new venture, i.e., in the pre-seed phase, have received particularly little attention so far.

Founding Angels, pre-seed venture capitalists and proof of concept centers are examples of such pre-foundation approaches. Festel and De Cleyn (2013) introduced the approach of Founding Angels, which provide financial and non-financial resources in the pre-founding stages of technology-based ventures. Festel et al. (2015) investigated activities of pre-seed venture capitalists, which are active in the pre-seed stage of university spin-offs. They find that these players provide financing for early stage technology development and in return receive a share in the associated IP rights. At incorporation of the venture, this IP is transferred and the venture capitalist provides additional funding and support services such as recruiting a management team (Festel et al. 2015). Pre-seed venture capitalists therefore follow a patent-based investment approach. Similarly, proof of concept centers and other public seed funds provide financial and non-financial resources specifically in the stage of technology commercialization, where funding is particularly scarce, with the goal of enhancing technology transfer from universities (Ayoub et al. 2016; Bradley et al. 2013; Maia and Claro 2013). Patent-based investment funds which commercialize patented technology through start-up creation and are therefore active in the pre-incorporation phase of a new venture can be embedded within this stream of entrepreneurial finance literature.

2.2.3. Patents as financial asset

There are also financial intermediaries that invest specifically in IPR assets (Fine and Palmer 2002). These players monetize the legal rights and have no control over the implicit knowledge underlying the IPR. In the case of patents, they accordingly do not finance activities driving technology commercialization but focus on patent sales or patent licensing where only the property right is part of the transactions. "This separation between an asset –

knowledge – and the property right attached to it is specific to intangible assets and intellectual property rights, since only in this case can the asset that is subject to a given property right be independently recreated by parties other than the rightful owner" (Fischer and Henkel 2012, p. 1531). These intermediaries are therefore active in the "markets for patents" as opposed to the "markets for technology" (Fischer and Henkel 2012, p. 1531) and "activities are one level removed from typical market participants, whose patent strategies are more likely to revolve around obtaining patents as upfront protection for the research, development, and production of actual goods" (Wang 2010, p. 160).

Funds active as patent licensors are often grouped under the term "patent aggregators". This umbrella term describes firms that "invest in the acquisition of ownership or control of patents from third parties, to achieve a return by monetizing these patents through use of security interest, licensing or litigation" (Krech et al. 2015, p. 2). They apply business models that make use of the exclusive nature and context-specific value of patents, which is the "value companies attach to patents when they use them for defensive or offensive reasons" (Benassi and Di Minin 2009, p. 80). Thereby, they apply an "ex post approach to licensing" (Fischer and Henkel 2012, p. 1530). Research on patent aggregators has often been included in the literature on technology market intermediaries, yet a clear differentiation of business models is not always provided (Krech et al. 2015; Wang 2010; Benassi and Di Minin 2009; Millien and Laurie 2007).

Wang (2010) and Kelley (2011) categorize patent market players into defensive and offensive aggregators. Defensive patent aggregators amass patent portfolios and provide licenses to their members, thereby insuring them against potential litigators. Offensive aggregators acquire patent portfolios of infringed patents and monetize them by enforcing a license or filing a lawsuit (Schwartz and Kesan 2014; Pohlmann and Opitz 2013; Fischer and Henkel 2012; Gregory 2007; Reitzig et al. 2007; Golden 2006). They thereby add "value through proofing the infringement and taking over the litigation risk" (Rüther 2012, p. 130). Benassi and Di Minin (2009) include patent enforcers in their taxonomy of patent brokers. Similarly, Krech et al. (2015) describe the business model of patent acquisition companies, patent assertion companies (offensive) and patent pools (defensive).

A significant amount of prior research on patents as financial assets deals with offensive aggregators, which are also referred to as "patent trolls" (e.g., Fischer and Henkel 2012; Reitzig et al. 2007) or as non-practicing entities (NPEs), indicating that they are "financial buyers" (Kelley 2011, p. 118) which do not use patents to cover own products. Academic literature on these players, which were the pioneers among patent aggregators in the US (Krech et al. 2015), has focused on describing the business model and its profitability, or on examining characteristics of patents monetized by NPEs (Fischer and Henkel 2012; Shrestha 2010; Henkel and Reitzig 2007; Reitzig et al. 2007). Furthermore, advantages and disadvantages of the business model and its effect on innovation and the economy as a whole are controversial (Shrestha 2010; Luman III and Dodson 2006). On the one hand, NPEs ensure that inventors who do not have the resources to enforce patents themselves can appropriate their return – the original purpose of the patent system. Besides, they accelerate the development of a market for patents (Fischer and Henkel 2012; Bessen et al. 2011). On the other hand, their activity is considered a "tax on invention" which deters producing firms from their core business, increases costs and eventually reduces social welfare and incentives for innovation (Bessen et al. 2011; Turner 2011; Davis 2008).

Through funds active as offensive aggregators, investors participate in a portfolio of patent rights and can benefit from the return generated from patent sales or licenses (Gredel et al. 2012). As previously stated, patent values are skewed and returns potentially high but risky (Gredel et al. 2012). As funds investing solely in the legal right of the patent focus on the value of the "right to exclude others from practicing the invention" (Hall and Harhoff 2012, p. 18) as opposed to the value of the underlying technology, they are exposed to the risk of invalidation. A startling example of this is the effect of new legislation in the US on patent litigation: The America Invents Act which went into effect in 2011 created, among other reforms to the patent system, new mechanisms for challenging the validity of granted patents in the US[3]. Under the new *inter partes* review, 87% of review processes completed at the Patent Trial and Appeal Board (PTAB 2017) led to at least one invalid claim as of the end of 2015

[3] See Jeruss et al. (2012), Bryant (2012), Armitage (2012) and Burton and Turner (2017) for an overview of reforms established through the America Invents Act.

(PTAB 2017). The regulatory change has led to a "reduction in liquidity, demand and value for patents" (Donegan 2015, p. 2) and a significant decrease of new patent litigation cases (Lloyd 2017; Unified Patents 2017). Moreover, a drop of litigation by NPEs against large companies has been observed (Lloyd 2017). The business model of patent enforcement has consequently become more difficult in the US. As a response to this recent development, NPEs are currently searching for alternative commercialization models, which in fact aim to reconnect the legal right with the underlying technology:

> "This intimate reconnecting of intellectual property to the business that it supports is a radical change of direction that will fundamentally restructure an IP industry that has grown bloated on patent monetization revenues. […] it will challenge non-practicing entities in particular to find new business models." (Donegan 2015, p. 2)

2.3. Patent-based investment funds

Nascent research on patent-based investment funds can be located at the intersection of literature on technology intermediaries, entrepreneurial financing models and patents as financial assets. Patent-based investment funds are a new phenomenon and business models are heterogeneous and in "full swing" (Benassi and Di Minin 2009, p. 79). Likewise, definitions used in extant research on these funds are not consistent. Patent-based investment funds in this thesis are defined as firms that acquire or gain control over patents or patentable inventions (Gredel et al. 2012) which differentiates them from technology intermediaries which do not invest their own capital and do not bear significant financial risk in a transaction (Benassi and Di Minin 2009) as well as from entrepreneurial finance models investing in already existing firms (Festel et al. 2015). They do not consider R&D or production as a core competence (Krech et al. 2015) which characterizes them as intermediaries. Patent-based investment funds invest privately or publicly raised funds and try to generate a return for their investors by commercializing patents and patentable inventions (Gredel et al. 2012). They are involved in technology transfer and do not only transfer the legal right (Gredel et al. 2012) which differentiates them from the business models described in the section on patents as financial assets.

Prior contributions examine the phenomenon from different angles and with different theoretical foci. Krech et al. (2015) provide a comprehensive typology of patent aggregating companies, some of which correspond to our definition and are active in the invention-to-innovation process (e.g., incubating funds). The theoretical focus lies on value propositions offered to original patent owners in the context of open innovation (Krech et al. 2015). Similarly, Benassi and Di Minin (2009) introduce patent deal makers and aggregators in their taxonomy of patent brokers. These players add value in a transaction as they actively invest in the technology in order to develop it further. Transaction cost and structural holes theory are applied to explain the phenomenon. Gredel et al. (2012) focus on investigating the business model of German patent-based investment funds and develop propositions on how they operate and why SMEs use them for external patent exploitation. With regard to business models commercializing patents via start-up creation, Elton et al. (2002) mention "business builders" which help companies to create spin-offs based on IP. Alternatively, the activities of Proof of Concept Centers, which support technology transfer from universities (Hayter and Link 2015; Bradley et al. 2013; Hayter 2013), as well as pre-incorporation models such as Founding Angels (Festel and De Cleyn 2013) or pre-seed venture capitalists (Festel et al. 2015) can be associated with our definition of patent-based investment funds.

Summing up different trends related to patent-based investment funds and highlighting research gaps, the relevance of this phenomenon as a promising avenue for research can be derived. On the one hand the wider context of our knowledge-based economy, increasing patenting activity and growing awareness of the need for external technology commercialization shows that a lot of patents and patentable inventions are lying idle and are available to be exploited – also by external parties. Business models enabling firms and universities to benefit from this unused potential can have a high impact on the economy as they "free up" inventions. On the other hand the search of investors for promising investment opportunities generating high return in a low interest environment implies that financial resources could be leveraged to invest in technology commercialization if new business models prove successful. Therefore it is relevant to understand players in the intersection of patents, technology com-

mercialization and financial intermediaries in general. More specifically, three research gaps can be emphasized.

First, research gaps exist in the field of business models active in technology commercialization, i.e., technology intermediaries and new entrepreneurial financing models. A systematic analysis of the entire spectrum of commercialization paths and concrete activities employed by patent-based investment funds does not exist. Whereas the majority of extant research on patent-based investment funds as technology intermediaries is limited to exploring business models based on technology commercialization via sale or licensing (Block et al. 2017; Krech et al. 2015; Gredel et al. 2012), funding of technology development followed by technology licensing has received little attention in entrepreneurial finance literature. Moreover, entrepreneurial finance literature is mostly restricted to post-incorporation models. Research on the activities and commercialization strategies of patent-based investment funds therefore fills a gap in research that has been overlooked both by entrepreneurial finance literature (Block et al. 2017; Ewens et al. 2015) and by research on technology intermediaries. It furthermore provides an opportunity to connect the two research streams (Audretsch et al. 2016).

Second, fund models active in the market for patents and in the market for technology have often been intermingled. Literature on technology market intermediaries lacks a clear differentiation between players in the market for patents and players in the market for technology. As Fischer and Henkel (2012) note, pure patent-transactions are often an "ex post approach to licensing" rather than "ex ante licensing" with technology transfer (Fischer and Henkel 2012, p. 1530) and therefore do not play in the market for technology. This thesis aims to investigate business models that are active in technology transfer as opposed to solely trading legal rights. This research focus makes it possible to answer the question of what the role of patent-based investment funds in technology commercialization is and whether those funds can contribute to leveraging the large unused potential of patented technologies lying idle. Further, it gives insight into the technology commercialization process and how the division of labor within this process can be structured. Focusing on patent exploitation business models outside of the courtroom corresponds to the recent trend in NPEs' activity, which is driven by regula-

tory changes in the US and which puts technology-based business models at the center of practitioners' attention.

Third, success factors of patent-based investment funds so far have not been explored. Literature on technology intermediaries often does not clearly differentiate between players which significantly invest and take financial risk and those which act rather as advisors and brokers (Benassi and Di Minin 2009). Researchers examining patent-based investment funds such as Krech et al. (2015) or Gredel et al. (2012) do not consider success factors of such models but concentrate on how patent providers can make use of them. They therefore neglect the aspect of financial intermediation and the point of view of investors. With respect to entrepreneurial finance literature, patent-based investment funds are an appropriate context in which to study how very early-stage and technology-based investment approaches can manage high agency risks and add value to their portfolio. This aspect is especially important because only sustainable business models will be reliable transaction partners in the long term and because some patent-based investment funds seem to have encountered major difficulties in creating a return for their investors (Matteo 2014).

Last, research on patent-based investment funds is relevant from a practical perspective. Both practitioners managing funds and practitioners active in external patent exploitation need to fully understand the landscape of fund models and commercialization strategies applied in an industry which is still emerging and very opaque. In particular, researching success factors will set the starting point of understanding best practices in this field and might trigger a critical review and improvement of patent-based investment fund concepts. It may also trigger increased collaboration between funds and technology owners, eventually enhancing innovation. Furthermore, this research has implications for the policy agenda of governments and regulators with respect to supporting technology transfer and fostering entrepreneurship and growth.

3. Research approach and main findings

The main body of this dissertation consists of two separate essays, each of which represents a distinct academic contribution. Each essay focuses on one of the research topics highlighted above: (1) activities and commercialization strategies of patent-based investment funds and (2) success factors of IP venturing funds as a sub-group of patent-based investment funds. They therefore both aim to answer specific research questions and provide independent theoretical and practical contributions. The first essay is an exploratory study of patent-based investment funds as a new type of intermediary in the knowledge spillover process. Its goal is to better understand activities and commercialization strategies of these funds and to link them to specific invention characteristics. The second essay focuses on funds which commercialize patents through IP venturing. It explores how funds' activities decrease agency costs and add value to the new firm, eventually leading to a higher return for the fund. An overview of the essays in this thesis is provided in Table 1.

Both essays are motivated by the fact that patent-based investment funds are a new phenomenon and have only recently become subject of empirical research. Moreover, business models of patent-based investment funds are very heterogeneous and dynamic. The nature of our research topic therefore lends itself best to exploring it via qualitative research (Yin 2003; Eisenhardt 1989). The analyses presented in the essays are based on two separate data collection efforts conducted by the author as part of this dissertation. Information about funds' activities and especially about concrete deals and performance data is sensitive, which makes the collection of primary data both challenging and valuable. The two essays follow an inductive approach, i.e., starting from an iterative analysis of qualitative data, emerging themes were compared to and embedded into relevant literature (Souitaris et al. 2012; Miles and Huberman 1994). The aim was to complement theory by reaching "theoretical generalization" (van de Ven 2007; Meuser and Nagel 1991).

Table 1: Overview of essays in this thesis

	Essay 1	Essay 2
Title	**From invention to innovation – patent-based investment funds as facilitators in the knowledge spillover process**	**Business builders, contractors, and entrepreneurs – an exploratory study of IP venturing funds**
Research question(s)	• How do patent-based investment funds commercialize patents or patentable inventions? • What are invention characteristics for different commercialization strategies?	• How do funds' activities decrease agency costs and add value, eventually leading to a higher return for the fund?
Main theoretical foundation	Knowledge spillover theory of entrepreneurship	Agency theory (management of agency risks in entrepreneurial finance)
Methodology	Qualitative research design (expert interviews)	Qualitative research design (multiple, embedded case studies)
Sample	21 experts in the field	6 cases on fund and deal level
Data collection	Semi-structured interviews (June 2015 – April 2016) and complementary archival data	Semi-structured interviews (April 2016 – December 2016) and complementary archival data
Main results	• Activities of patent-based investment funds decreasing knowledge filters • Four distinct commercialization strategies applied by funds • Set of technology characteristics which determine suitability for commercialization strategy	• Six propositions on factors that increase or moderate the financial return of IP venturing funds • Dichotomy of IP venturing fund models: opportunity-based and technology-based investment styles
Main theoretical implication	Introduction of the role of funds in the KSTE and evidence for division of labor in the knowledge spillover process	New mechanisms in managing high agency risks in the very early stages of technology commercialization projects
Main practical implication	Overview of commercialization strategies and link to invention characteristics informs fund managers and managers active in external IP commercialization in general	First step towards a best-practice list of IP venturing informs fund managers, other pre-seed and seed fund models and policy makers

Essay 1 investigates the business model of patent-based investment funds more generally. The primary aim is to shed light on a broad spectrum of fund business models. The following research questions are examined: How do patent-based investment funds commercialize patents or patentable inventions? What are invention characteristics for different commercialization strategies? To answer these questions 21 interviews with experts in the field of patent commercialization and patent-based investment funds were conducted and complemented with archival data. Data was collected between June 2015 and April 2016, transcribed and analyzed. Drawing on the knowledge spillover theory of entrepreneurship as well as the nascent literature on patent-based investment funds, findings were linked to existing theory and constantly compared with extant research. In addition, the emerging theme of the impact of technology characteristics on the commercialization pathways analyzed was embedded in the corresponding literature on entrepreneurship and technology transfer research.

The findings suggest that patent-based investment funds can actively decrease knowledge filters and therefore act as facilitators in the transformation of invention into innovation (Acs and Sanders 2012). A classification of commercialization strategies is proposed. By differentiating mode, locus and length of the phase in which funds develop the technology underlying the IP, four distinct strategies can be established: "Technology licensing", "IP venturing – early M&A", "IP venturing – long-term incubation" and "IP venturing – extension". The relation between these strategies and invention characteristics is examined. A set of invention characteristics is presented whose dimensions determine how suitable a technology is for each of the commercialization strategies.

The essay contributes to the knowledge spillover theory of entrepreneurship and the knowledge filter model by providing empirical insights into the division of labor between the inventor and the commercializer in the knowledge spillover process. Funds can take over the "entrepreneurial absorptive capacity" (Qian and Acs 2013, p. 185), decrease institutional filters and eliminate resource and competence constraints (Guerrero and Urbano 2014; Hayter 2013), thereby creating "new opportunities in a Schumpeterian sense" (Ghio et al. 2015, p. 14). Moreover, findings expand the nascent literature on patent-based investment funds and, more generally, on patent and technology intermediaries. Besides, we introduce patent-

based investment funds as an emerging entrepreneurial financing model in the very early stage technology development (Festel et al. 2015). Last, the essay contributes to research on entrepreneurship and technology transfer literature aiming to link commercialization modes to technology characteristics (Block et al. 2013; Festel 2013; Festel and De Cleyn 2013; Eckhardt and Shane 2010; Shane 2001a; Henderson 1993).

IP venturing emerges from the research presented in the first essay as one of the commercialization strategies employed by patent-based investment funds. The approach of forming a new start-up around IP by using an external management team is striking. This is because it opposes the general approach of players in entrepreneurial finance such as traditional venture capital which are active post-incorporation and which often focus on selecting the best management teams (Baum and Silverman 2004). The business model of IP venturing, however, has never been explicitly investigated in literature. The second essay aims to fill this research gap and in addition focuses on the exploration of success factors of IP venturing funds as a sub-group of patent-based investment funds. Therefore, it builds on the first essay and digs deeper into the phenomenon of IP venturing.

Essay 2 analyzes the phenomenon of IP venturing at the fund and deal level with the aim of generating insights into success factors of this specific investment approach. The following research question is examined: How do funds' activities decrease agency costs and add value, eventually leading to a higher return for the fund? A multi-case, embedded case study design was employed. Using a purposeful sampling approach, six IP venturing funds in the US and UK were selected (Patton 1990). In addition, one successful commercialization was chosen per fund. Semi-structured interviews with key informants of funds and newly created ventures were conducted and complemented by an extensive review of archival data. Primary in-depth data on IP venturing funds has never been analyzed in extant literature and is therefore particularly valuable. Findings are embedded into agency theory in the context of entrepreneurial finance.

It is shown that IP venturing funds act as active business builders and thereby add value and decrease agency costs. They get involved in day-to-day management of the new venture and

recruit a surrogate management team. They also provide both business-related and technical support services that go beyond the value-adding activities of traditional venture capital funds. It is proposed that a dichotomy exists regarding investment styles employed by IP venturing funds. In an opportunity-driven investment style the fund acts as entrepreneur and takes over the task of opportunity recognition. Information asymmetry between entrepreneur and resource provider is eliminated and agency costs are decreased. In a technology-driven investment style IP venturing funds apply novel contracting approaches such as pre-defined valuations and cap tables in order to limit due diligence and valuation costs. It is proposed that these activities will lead to an increased return for the fund.

These findings contribute to theory on how financial intermediaries can manage agency costs in early stage technology commercialization as well as to literature about new investment models in entrepreneurial finance. IP venturing funds are introduced as players in the pre-seed stage which can complement traditional providers of financial resources in the earliest stages of a new venture. Broader implications refer to research on the entrepreneurial process as we provide evidence that funds can take over the key task of opportunity recognition (Shane 2000; Venkataraman 1997; Kirzner 1973). Last, our findings support the argument that entrepreneurial resources can be considered an "eclectically sourced stock" (Murray 1996).

II. Essays

1. Essay 1: From invention to innovation – patent-based investment funds as facilitators in the knowledge spillover process

Abstract

Not all inventions stemming from academic or corporate research can be successfully transformed into innovations. Drawing on the knowledge spillover theory of entrepreneurship we investigate the phenomenon of patent-based investment funds as a new type of intermediary in the knowledge spillover process, which could facilitate this transformation. Using a qualitative research design we analyze data from 21 expert interviews and complementary archival data. We find common characteristics of funds' activities which decrease knowledge filters and fill the financing gap in the early stages of technology development. We propose a classification of commercialization strategies and link them to a specific set of invention characteristics. Our insights contribute to the knowledge spillover theory of entrepreneurship and to the knowledge filter model by providing empirical evidence for the division of labor between knowledge creator and commercialization agent. In addition, they refine the literature on patent-based investment funds by providing a classification of the entire commercialization spectrum used by funds and add to extant theorizing on how the nature of a technology determines its commercialization.

Keywords: patent-based investment funds; technology intermediaries; knowledge spillover theory of entrepreneurship; invention characteristics

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1.1. Introduction

Despite the acknowledged importance of innovation for the economy, creators of new knowledge are not always able or willing to transform their inventions into cash-flow generating assets. The knowledge spillover theory of entrepreneurship (KSTE) provides the foundation to this phenomenon, stating that knowledge filters exist which impede the transformation of knowledge into marketable products (Braunerhjelm et al. 2010; Carlsson et al. 2009; Acs et al. 2004; Glaeser et al. 1992). According to the theory, these filters can be penetrated by economic agents who are not necessarily the creators of this knowledge and who consequently drive forward commercialization (Ghio et al. 2015; Block et al. 2013; Acs and Sanders 2012; Braunerhjelm and Svensson 2010; Acs et al. 2009b).

The role of intermediaries, playing in between creators and ultimate users of knowledge (Benassi and Di Minin 2009), has not been researched in the context of the KSTE. The rather new phenomenon of patent-based investment funds, which provide capital and expertise to add value to patents and patentable inventions, has only recently attracted the attention of academics. Business models of these players are heterogeneous and dynamic. Contributions have therefore provided typologies of patent intermediaries or patent aggregating companies in general (Krech et al. 2015; Wang 2010; Benassi and Di Minin 2009; Elton et al. 2002) and explored how inventing companies can make use of these market players (Krech et al. 2015; Gredel et al. 2012; Wang 2010; Benassi and Di Minin 2009; Chesbrough 2006a; Elton et al. 2002).

Little is known, however, about specific activities of patent-based investment funds and the distinct commercialization strategies employed by them. The relation between these commercialization strategies and specific invention characteristics is also not well understood so far (Eckhardt and Shane 2010; Shane 2001a). Such insights are relevant for academics in order to understand how the division of labor in the KSTE can be structured and what role intermediaries can potentially play in decreasing knowledge filters (Acs and Sanders 2012). Furthermore, practitioners can benefit from an increased understanding of patent commercialization strategies and how they are linked to invention and investment characteristics. This is espe-

cially relevant, as funds today still search for the best approach to making money out of patents and constantly innovate their own business models and strategies (Matteo 2014).

We therefore strive to add to extant research by exploring the "how" question with regard to patent-based investment funds' activities and commercialization strategies. Our first research question is:

RQ1: How do patent-based investment funds commercialize patents or patentable inventions?

With regard to this first research question we find that four distinct commercialization strategies can be differentiated. We subsequently aim to investigate invention characteristics which can be linked to each of these commercialization strategies. This composes the second research question:

RQ2: What are invention characteristics for different commercialization strategies?

Since a variety of terms exist in the literature to describe the group of intermediaries in our research focus, we define patent-based investment funds as firms which acquire or gain control over patents or patentable inventions (Gredel et al. 2012) and which do not consider R&D or production as a core competence (Krech et al. 2015). They invest privately or publicly raised funds and try to generate a return for their investors by commercializing patents and inventions (Gredel et al. 2012).

Based on the analysis of qualitative data collected via 21 semi-structured interviews with experts in the field as well as complementary archival data, we propose that business models of patent-based investment funds follow common activities in their investment process which can decrease knowledge filters. They therefore can act as facilitators in the transformation of invention into innovation and create new opportunities in a Schumpeterian sense. We also present a classification of commercialization strategies applied by funds which can be differentiated along mode, locus and length of the development phase: "Technology licensing", "IP venturing – early M&A", "IP venturing – long-term incubation" and "IP venturing – extension". Last, we propose a set of invention characteristics which determine the suitability of patents and patentable inventions for each of the proposed commercialization strategies.

These characteristics have implications for the selection of patent and patentable inventions by funds as well as for investment characteristics of commercialization projects.

Our findings contribute to the KSTE by introducing patent-based investment funds as intermediaries in the knowledge spillover process (Acs and Sanders 2012), as well as by shedding light on the division of labor (Ghio et al. 2015; Acs and Sanders 2012; Jensen and Thursby 2001) between the knowledge creator and the commercializer. With regard to extant literature on patent-based investment funds, this study complements earlier typologies of intermediaries by considering the entire spectrum of patent-based investment funds' business models contributing to the transition from invention to innovation with varying degrees of value-add to the underlying technology (Krech et al. 2015; Gredel et al. 2012; Kelley 2011; Wang 2010; Benassi and Di Minin 2009). Second, we complement extant literature in entrepreneurship and technology transfer research on the impact of invention characteristics on commercialization in general and different pathways in particular (Eckhardt and Shane 2010; Shane 2001a). Practical implications refer to a better understanding of critical commercialization activities and the selection of appropriate commercialization strategies for a given invention, which is relevant for both fund managers and managers dealing with external patent exploitation in general.

The paper is structured as follows: First, we review the theoretical background and literature with regard to the KSTE, patent-based investment funds and the impact of invention characteristics on commercialization of knowledge. Subsequently, we describe the research design and methods applied to answer our research questions. Third, we present and discuss our results. We conclude with a summary of our theoretical and practical implications, limitations of our study and need for further research.

1.2. Theoretical background and literature overview

1.2.1. The knowledge spillover theory of entrepreneurship

The knowledge spillover process

It is widely accepted in the literature that new knowledge created in a society leads to economic growth. While the endogenous growth theory assumes that knowledge spillovers occur automatically (Romer 1990), the knowledge spillover theory of entrepreneurship (KSTE) states that entrepreneurship catalyzes the transformation from knowledge to economic growth (Braunerhjelm et al. 2010; Acs et al. 2009b). In this theory, entrepreneurship, i.e., the creation of knowledge-based ventures, is considered one major channel facilitating the commercialization of knowledge and the appropriation of returns from knowledge spillovers (Ghio et al. 2015). The alternative route to transfer knowledge into marketable products is licensing (Kirchberger and Pohl 2016; Carlsson et al. 2009). However, this route has gotten comparably little attention in KSTE literature so far.

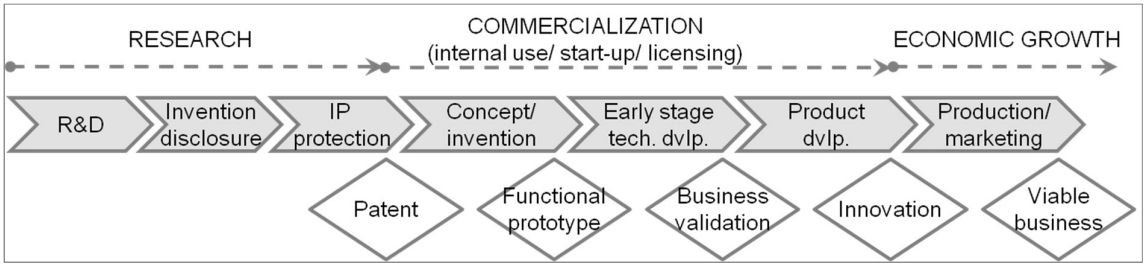
Figure 4 illustrates the knowledge spillover process with a particular emphasis on the transition from invention, defined as the outcome of R&D that can be disclosed and protected by IPR, to innovation, defined as the stage where a new product or process generates turnover or productivity increases (Block et al. 2013). The stages in between include the development of a technical concept and prototype as well as the early stage development, where "the technology is reduced to industrial practice, a production process is defined from which costs can be estimated, and a market appropriate to the demonstrated performance specifications is identified and quantified" (Auerswald and Branscomb 2003, p. 229). Afterwards, the product is developed, production starts and the market is explored through marketing and sales efforts (Auerswald and Branscomb 2003).

According to the KSTE, entrepreneurship fosters aspects such as innovation, competition and diversity among firms (Audretsch 2007), as well as employment and learning (Block et al. 2013). These factors will finally lead to economic growth. As an example, the study of Block et al. (2013) focuses on the aspect of innovation, which can be measured by the "turnover of

new products, increases in productivity or decreases in production cost as a result of introducing new processes, or customer satisfaction with new products or services" (Block et al. 2013, p. 701).

Figure 4: The knowledge spillover process

Source: Own illustration based on Guerrero and Urbano (2014), Block et al. (2013), Acs and Sanders (2012), Carlsson et al. (2009), Auerswald and Branscomb (2003)



Many contributions to the KSTE rely on the assumption that knowledge spillovers can be commercialized outside the source of knowledge creation (Ghio et al. 2015; Block et al. 2013; Acs and Sanders 2012; Braunerhjelm and Svensson 2010). Thereby, economic agents, which are not necessarily the inventors, can transfer inventions into marketable products (Block et al. 2013; Acs and Sanders 2012; Brouwer 2002). This division of labor in a Schumpeterian sense assumes separate activities and different prerequisites for the creators of invention and commercialization agents (Schumpeter 1934) and can therefore increase efficiency (Braunerhjelm and Svensson 2010). An example of such a prerequisite in the case of new venture creation is the entrepreneur's capacity to deal with a high level of risk and uncertainty (Block et al. 2013).

Knowledge spillovers generally occur due to the non-excludable and non-rival nature of knowledge (Audretsch and Stephan 1999). In the case of codified knowledge in the form of patents as source of entrepreneurial opportunities the invention is publicly disclosed and rents from commercialization can be appropriated by the inventor. To maximize economic benefit, Acs and Sanders (2012) argue that in the event of labor division, these rents must be appropriately shared between the inventor and the commercializer. Stronger IPR protection increases rents for the inventor and encourages further research. However, an entrepreneur will only develop and commercialize the invention if "expected (risk-adjusted) returns justify that in-

vestment" (Acs and Sanders 2012, p. 803). The respective bargaining power is dependent on the strength of patent protection, but other factors such as institutional aspects or the involvement of intermediaries might also play a role (Acs and Sanders 2012).

Although the division of labor between the knowledge creator and the commercializer is an important assumption of the KSTE, there is very little empirical insight into how this transition can actually be structured and what the role of intermediaries in this regard is. Patent-based investment funds, which act as economic agents active in the invention-to-innovation transition, have to our knowledge never been investigated in the context of KSTE. An increased understanding of this phenomenon can provide interesting insights into the mechanisms of the division of labor.

Knowledge filters and the financing gap

The KSTE acknowledges the existence of knowledge filters which impede the commercialization of knowledge (Braunerhjelm et al. 2010; Acs et al. 2004; Glaeser et al. 1992). Knowledge filters can be defined as "all the barriers inhibiting the conversion of knowledge produced in R&D laboratories of incumbent firms and in universities into commercialized knowledge" (Ghio et al. 2015, pp. 9–10). They hamper both commercialization within the organization of the knowledge creator as well as spillovers to other agents who can exploit them (Ghio et al. 2015; Block et al. 2013; Acs et al. 2009b; Carlsson et al. 2009; Acs et al. 2004). Guerrero and Urbano (2014) and Carlsson et al. (2009) establish three distinct filters, which are depicted in Figure 5. The first concerns primarily academic basic research and is created by, e.g., organizational barriers, regulation and university policies as well as attitudes and incentives (Gerbin and Drnovsek 2016; Guerrero and Urbano 2014; Auerswald and Branscomb 2003). On the individual (inventor) level, it is shown that attitudes towards entrepreneurship and perceived behavioral control, i.e., the desirability and feasibility of entrepreneurial activities, can hamper academics' start-up intentions and consequent actions (Gerbin and Drnovsek 2016; Guerrero and Urbano 2014; Auerswald and Branscomb 2003), which leads to unexploited opportunities. The institutional filter separates knowledge from potentially economically useful knowledge (Carlsson et al. 2009; Acs et al. 2004), which is consequently disclosed and con-

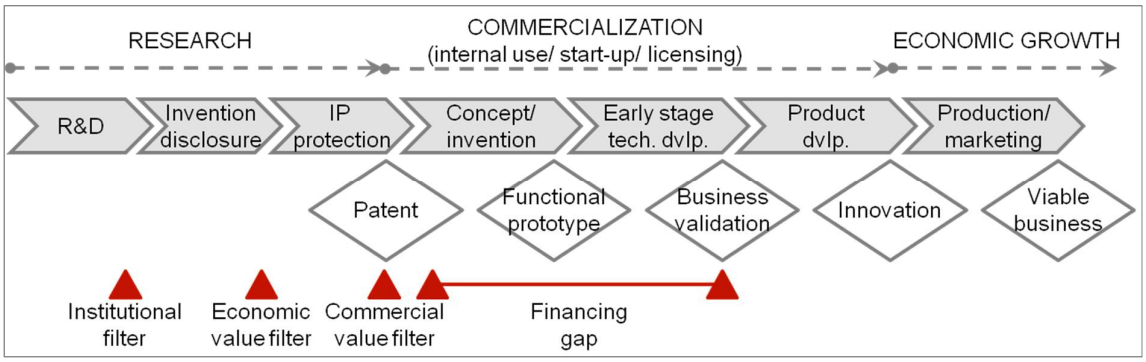
verted to intellectual property (IP). The subsequent filters determine whether the patent protecting the invention is actually approved and whether it is then commercialized, internally or externally, via licensing or start-up creation (Guerrero and Urbano 2014; Carlsson et al. 2009). Even if inventions reach the stage of IP protection, they are not necessarily exploited. In fact, Giuri et al. (2007) find that "many patents are never exploited, and only a few of them yield economic returns" (p. 1117). According to a survey of European granted patents, 17.4% of all EU6 patents owned by companies, universities and other research institutions are lying idle (Giuri et al. 2007). This unused knowledge might produce additional opportunities for entrepreneurs when knowledge filters can be reduced or overcome (Acs et al. 2004).

In addition to these knowledge filters established within the KSTE literature, a financing gap can be observed in the transfer of invention to innovation, which is sometimes referred to as the "valley of death" (Auerswald and Branscomb 2003, p. 229). Funding sources are available for basic research through corporate or government agencies as well as for the stages beyond product development primarily through venture capital. The innovation gap, however, refers to the lack of financing in those stages that we describe as concept development and early stage technology development (Maia and Claro 2013; Mason and Harrison 2004; Auerswald and Branscomb 2003). These stages are characterized by high information asymmetries and an extremely high uncertainty regarding technology and the market (Maia and Claro 2013; Auerswald and Branscomb 2003). The perception of higher risk (Mason and Harrison 2004) and the apparent inability of investors to achieve returns that compensate for this risk (Auerswald and Branscomb 2003) subsequently deter private investments. This holds both for inventions from universities and research institutions as well as for corporate inventions which are outside the company's core competencies and focus (Auerswald and Branscomb 2003).

Given the importance of commercialization for economic growth, it is important to understand how the filters described above and summarized in Figure 5 can be penetrated. Understanding the role of intermediaries such as patent-based investment funds in this regard is therefore both of theoretical and practical interest.

Figure 5: Knowledge filters and financing gap in the knowledge spillover process

Source: Own illustration based on Guerrero and Urbano (2014), Block et al. (2013), Acs and Sanders (2012), Carlsson et al. (2009), Auerswald and Branscomb (2003)



1.2.2. Patent-based investment funds

Technology intermediaries and other players providing early stage financing

A wide range of intermediaries exists in the concept and early stage technology development stages of the invention-to-innovation process. Business models of these players are very heterogeneous and in "full swing" (Benassi and Di Minin 2009, p. 79) as new business models evolve and others cease to exist (Krech et al. 2015; Benassi and Di Minin 2009). Auerswald and Branscomb (2003) even describe these stages as a "struggle between institutional forms and approaches" (Auerswald and Branscomb 2003, p. 237) with regard to different financing models. Due to this variety and dynamic, extant literature does not provide a consistent overview of active players (Audretsch et al. 2016) and even terminology and classifications differ.

One literature stream in this context focuses specifically on patent and technology intermediaries. These intermediaries are a rather new phenomenon and have found attention in academic literature only recently. Rising interest was motivated by the emergence of various intermediaries with new and innovative exploitation strategies in the US and Europe. For example, there was a surge of public funds issued by globally operating banks and IP firms in Germany that focused on buying, refining and reselling or licensing patents in the years 2005-2008. The literature on intermediaries in general and patent-based investment funds in particular is limited to patent commercialization via sale or licensing. The value that intermediaries add to a technology varies depending on their value proposition and commercialization approach.

Benassi and Di Minin (2009) provide a taxonomy of patent brokers, which include, e.g., patent deal makers and aggregators. These types of intermediaries "add high value and high risk" (Benassi and Di Minin 2009, p. 82) in a patent transaction as they invest in the patents by acquiring or developing the underlying technology, and actively look for customers. However, aggregators are not further differentiated. Krech et al. (2015) present a comprehensive analysis and typology of patent aggregating companies and identify several fund models (e.g., incubating funds, acquisition companies) which apply commercialization strategies based on licensing with varying degrees of technology development and technology transfer (Krech et al. 2015). Gredel et al. (2012) focus their exploration on aforementioned German patent funds that also rely on a pure licensing model.

Other business models that are active in the concept and early stage technology development stages are based on commercialization through start-up creation. Traditional players providing financial support in these stages include, e.g., business angels or government grant programs (Auerswald and Branscomb 2003). Moreover, new models are emerging to address this gap, such as Proof of Concept Centers, which are often associated with university technology transfer offices (Audretsch et al. 2016; Hayter and Link 2015; Bradley et al. 2013; Hayter 2013) and Founding Angels (Festel and De Cleyn 2013). These approaches, however, are not necessarily based purely on patents and their underlying technology, but often refer to early investments in existing start-ups. Funds, which explicitly invest in IP and commercialize the underlying technology through a newly founded start-up, have very rarely been mentioned in the literature. They are referred to as "business builders", which "help companies create new ventures based on patents or technologies" (Elton et al. 2002, p. 5) or pre-seed venture capitalists (Festel et al. 2015).

Fundamentals of patent-based investment funds

Due to the variety of terms and underlying meaning which exist in literature, we rely on the rather broad term of patent-based investment funds which was characterized by Gredel et al. (2012). We hence define patent-based investment funds using three criteria:

- Patent-based investment funds are firms that acquire or gain control over patents or patentable inventions (Gredel et al. 2012).
- These funds do not consider R&D or production as a core competence (Krech et al. 2015).
- These funds invest privately or publicly raised funds and try to generate a return for their investors by commercializing patents and inventions (Gredel et al. 2012).

We acknowledge a broader commercialization approach than previous studies in the context of technology intermediaries and early stage financing and consider all commercialization pathways, i.e., licensing and start-up creation. Following Gredel et al. (2012), the funds' assets can therefore not only consist of "inventions, patents or rights on those" (p. 539), but also of shares of new ventures in the case in which patent commercialization takes place through start-up creation. Patent-based investment funds consequently generate their income from royalties, patent sales and/or the sales of company shares through a trade sale or an IPO.

As we want to investigate the role of funds in the knowledge spillover process, we note that the technology which may be protected by an IP right is the central element of the funds' commercialization efforts. Therefore, we exclude several business models used by patent intermediaries which play only in the market for patents and which do not directly contribute to the transfer of invention to innovation (Krech et al. 2015; Gredel et al. 2012): funds based on patent licensing and enforcement/ litigation (so-called "patent trolls"), patent pooling firms that amass patents for defensive reasons, non-commercial patent funds as well as royalty monetization companies (Krech et al. 2015).

Funds which correspond to our definition are, for example, large patent aggregating companies, whose main business model is based on patent licensing and enforcement and which are looking for monetization options outside the court room (Lloyd 2015) or early stage venture capital firms which make use of approaches that are based on patents or patentable inventions (Festel et al. 2015). There are also new stand-alone approaches of private patent-based investment funds, such as the German patent funds introduced by Gredel et al. (2012) and Krech et al. (2015).

Patents as an asset class

The emergence of patent-based investment funds has not only found attention in the field of external patent exploitation and markets for technology. It has also fueled the discussion on IP investments as a new source of attractive returns for investors. As Fine and Palmer (2002) argue, IP is increasingly considered by investors as an independent alternative asset-class and should therefore receive more attention. In this context, patent-based investment funds offer an opportunity for private and institutional investors to take a share in an actively managed portfolio of patent rights and to benefit from the return generated through cash flows from patent sales or licensing royalties as well as from trade sales or IPOs in the case of a newly formed venture. Academics and practitioners alike have stated the low correlation of patents with traditional assets (Rensch 2015; Gredel et al. 2012). Besides, as patent values have been found to be highly skewed (Hall et al. 2005; Scherer 1965), returns might theoretically be high if informational asymmetries can be appropriately reduced. On the other hand, direct investments are considered to be extremely risky due to this skewness. Also, patents can become worthless as the legal right can be invalidated and the underlying technology can be replaced by a new one (Gredel et al. 2012).

More specific or empirically tested asset characteristics of different IP investment models are not well known. Anecdotal evidence indicates that not all patent-based investment funds observed in the market were successful, both in generating returns for investors and in matching patent or technology providers with customers. Antecedents of successful fund concepts have not been explored systematically (Krech et al. 2015; Benassi and Di Minin 2009). However, Gredel et al. (2012) stress the importance of the inventor involvement in ongoing R&D work during the holding period of the fund and conjecture that incentives encouraging this involvement "might not have enough motivational impact when new patents on inventions resulting from the ongoing R&D become the sole property of the [patent-based investment fund]" (Gredel et al. 2012, p. 546). Shedding light on mechanisms which contribute to a successful commercialization of patents and their underlying technologies forms the basis of understanding how sustainable and stable such business models are.

1.2.3. Invention characteristics and their impact on commercialization

This study is based on exploratory, qualitative research with the intention of investigating the phenomenon of patent-based investment funds. After we explored the activities and role of patent-based investment funds and identified distinct commercialization strategies (RQ 1), one dominant topic emerged from the iterative approach of going back and forth between the data, emerging concepts and extant literature: the dependency of identified strategies on specific invention characteristics (RQ 2). We follow the current practice of qualitative studies (e.g., Souitaris et al. 2012; Pratt 2008) and give an introduction to prior findings which eventually informed our study.

The approach of explaining commercialization efforts and modes using the nature of a given technology is an established one in entrepreneurship literature (e.g., Shane 2001a; Henderson 1993). It complements the investigation of factors on the industry level, which refer, e.g., to the structure and maturity of an industry (Audretsch 1995), and of factors on an individual level, which refer to the personal characteristics of the entrepreneur (Roberts 1991). Six invention characteristics have been identified:

First, the breadth of IP protection positively influences commercialization of technology in general (Eckhardt and Shane 2010) as it ensures that returns can be appropriated. This is relevant both in the start-up context where patents ensure competitive advantage for the time in which no other assets are built up (Shane 2001b; Teece 1986) and investors often require patents (Nerkar and Shane 2007; Lerner 1994), as well as in the case of licensing (Eckhardt and Shane 2010; Arrow 1962). Second, the importance and the magnitude of economic value play an important role. This again holds for commercialization in general (Eckhardt and Shane 2010; Schmookler 1965), but is even more important for start-up creation where future cash flows need to compensate for the investment and risks associated with it (Shane 2001a).

Third, a specifically path-specific factor is the radicalness of the invention. Whereas radical innovations "embody a new technology that results in a new market infrastructure" (Garcia and Calantone 2002, p. 120), incremental innovations can be "defined as products that provide new features, benefits, or improvements to the existing technology in the existing market"

(Garcia and Calantone 2002, p. 123). Shane (2001a) finds that the more radical an invention is, the higher the probability of exploitation through a new start-up. Block et al. (2013) conjecture that knowledge spillovers leading to radical innovations are more likely to be exploited by start-ups (Block et al. 2013; Arrow 1962). The reason for this is that incumbents are reluctant to commercialize inventions which require a set of new skills and which carry the danger of cannibalization (Shane 2001a; Arrow 1962). Moreover, their focus is biased towards inventions close to previous inventions in their competence field through existing routines (Eckhardt and Shane 2010; Henderson 1993). On the other side, "established firms are more likely than entrants to invest in incremental innovation" (Block et al. 2013, p. 714). In this case, knowledge transfer via technology licensing might be more relevant (Eckhardt and Shane 2010).

Fourth, the appropriate commercialization path might be dependent on the capital intensity of commercializing a given technology. Eckhardt and Shane (2010) argue that licensing is more likely if capital intensity is high and if entrepreneurs are financially constrained (Eckhardt and Shane 2010). Furthermore, licensing is considered to be faster to implement (Eckhardt and Shane 2010) especially because it is the suitable commercialization path when infrastructure and complementary assets are already available to incumbents.

The last factor, which is especially relevant to knowledge transfer in the market for technology, i.e., licensing, is the degree of knowledge ambiguity. Knowledge ambiguity can be defined as "the inherent and irreducible uncertainty as to precisely what the underlying knowledge components and sources are and how they interact" (van Wijk et al. 2008, p. 833). According to Eckhardt and Shane (2010), "markets are more likely to be employed when the opportunity can be well-codified" (p. 68). This relates to findings in the literature on technology transfer between organizations and strategic alliances (e.g., van Wijk et al. 2008; Simonin 1999). Simonin (1999) finds that ambiguity mediates factors such as tacitness, complexity and prior experience of the firm acquiring a technology and negatively influences knowledge transfer between large companies in the US.

Although many arguments and some empirical evidence exist, so far no comprehensive set of path-specific criteria for technology commercialization exists. This explains recent calls for research aiming at a better understanding of decision criteria for technology owners to use when choosing the optimal commercialization path (Festel 2013) and of the effect of radical versus incremental inventions (Block et al. 2013). Existing evidence is based on the commercialization of university inventions or technology transfer between companies. Invention characteristics in the context of commercialization by technology intermediaries have so far not been studied. These players are a particularly interesting phenomenon to study when investigating this topic as they are specialized and experienced in IP commercialization and have particular IP management competencies (Gredel et al. 2012). This implies that they might make more sophisticated decisions about commercialization strategies as they are less limited in their options.

1.3. Methods

As patent-based investment funds represent a new empirical phenomenon, which – as of now – is little understood, we choose an exploratory, qualitative research design to answer the research questions (Cunningham et al. 2016; Yin 2003; Eisenhardt 1989). The goal is to reach a "theoretical generalization" (Meuser and Nagel 1991) from the collected data and to complement and refine the existing literature.

1.3.1. General context and sample

Interviews with experts in the field of IP commercialization and patent-based investment funds seemed most appropriate to investigate commercialization strategies applied by funds; business models of these funds are diverse, dynamic and fast moving, indicating that the industry is still in an experimental phase. In addition, information about funds' characteristics is often private and sensitive, which is even more pronounced for business models which have not performed as expected. In this context, expert interviews not only shed light on the broad spectrum of existing business models but also provide a differentiated and honest view on

activities and the sustainability of certain fund models. Purely focusing on selected case studies would have restricted such insights.

Experts in this context are "part of the field of action, which constitutes the research object" (Meuser and Nagel 1991). For the purpose of this study, they are defined as (1) professionals knowledgeable in the field of IP commercialization, such as principal informants of IP service providers or corporate IP divisions, (2) professionals in the field of fund structures and set-ups for early stage technology investments, such as investment managers of venture capital funds and/or (3) professionals with inside knowledge of patent-based investment funds. The sample was formed by collecting a long list of appropriate companies and individuals based on secondary research, and selecting purposefully according to the three criteria described above as well as a geographic focus. Purposeful sampling allowed us to select interview partners who are most knowledgeable about the topic and who can cover all aspects highlighted in this study (Patton 1990). Moreover, we used identified expert informants to find and select further interview partners. All experts in the sample are based in Germany, Switzerland, the UK or the US. We chose this geographical focus because interview partners were expected to have expertise in those regions currently most relevant for patent and technology trading, namely Europe and the US (Rüther 2012). The sample characteristics are shown in Table 2.

1.3.2. Data

Data was collected between June 2015 and April 2016. Multiple data sources were used in order to enable data triangulation and to increase internal validity (Santos and Eisenhardt 2009; Yin 2003). The primary sources of data were semi-structured interviews, which were conducted in person as well as by phone. In all 21 interviews were conducted, which were between 33 and 97 minutes long. Overall, ~20 hours of interview material were recorded and transcribed. In addition to the open nature of guiding questions, the course of the interviews was open for new topics proposed by the interviewee as suggested by Flick (2009) and Meuser and Nagel (1991). Potential interviewees were contacted via email that included a short description of the content and process of the overall research project in order to encourage participation. Out of 27 potential interviewees contacted, 22 persons granted an interview and

Table 2: Sample characteristics

#	Category	Position	Regional focus	Industry focus	Interview place/date	Length of interview	Archival data
#1	(1) IP services	Founder/ CEO	Germany	All	Phone/ 07.12.2015	62 min	Website, brochures, E-mails
#2	(1) IP services	Founder/ CEO	Germany	All	Phone/ 12.11.2015	63 min	Website, brochures
#3	(1) Tech transfer (public research)	Head	Germany	All	Munich/ 08.12.2015	67 min	Website
#4	(1,3) IP services	Patent Attorney	Germany	All	Phone/ 09.12.2015	57 min	Blog entries
#5	(3) IP fund	Portfolio Manager	Switzerland	All	Phone/ 23.11.2015	36 min	Website, publ. interviews
#6	(2) Venture capital	Director	Germany	All	Phone/ 02.12.2015	33 min	Website
#7	(1) IP services	Managing Partner	Germany	All	Munich/ 02.06.2015	50 min	-
#8	(1) Tech transfer (WIPO)	Senior Counsellor	Switzerland	All	Phone/ 25.02.2016	64 min	-
#9	(1) Innovation services	Founder/ CEO	UK	All	Phone/ 15.12.2015	63 min	Website, E-mails
#10	(2) Venture capital	Founder	UK	All	Phone/ 07.03.2016	36 min	-
#11	(3) IP fund	CEO Europe	UK	All	Phone/ 06.04.2016	97 min	Blog entries, Website
#12	(2) Venture capital	Venture Partner	Germany	Bio-Tech	Munich/ 07.12.2015	67 min	Website
#13	(3) IP fund	Vice President (former)	US	All	Phone/ 24.11.2015	55 min	-
#14	(1) IP services; Tech transfer (univ.)	Vice President	US	All	Phone/ 03.12.2015	47 min	Website, brochures
#15	(1) IP services	Principal	US	All	Phone/ 16.11.2015	37 min	-
#16	(1) IP services; Tech transfer (univ.)	Senior manager	US	All	Phone/ 13.01.2016	58 min	-
#17	(2) Venture capital	General Partner	US	All	Phone/ 19.01.2016	49 min	-
#18	(1) IP services	Attorney	US	IT, Life sciences	Phone/ 17.12.2015	61 min	-
#19	(2) Venture capital	Managing Director	US	Life sciences	Phone/ 18.01.2016	55 min	-
#20	(1) Tech transfer (corporate)	Vice President IP Strategy	US	MedTech	Phone/ 19.01.2016	55 min	-
#21	(1) IP services; Tech transfer (univ.)	President/ CEO	US	MedTech	Phone/ 22.02.2016 29.02.2016	58 min 45 min	-

Note: (1) professionals knowledgeable in the field of IP commercialization; (2) professionals in the field of fund structures and set-ups for early stage technology investments; (3) professionals with inside knowledge on patent-based investment funds

one interview was stopped after the introduction as the person stated she was not knowledgeable in the field. Guiding questions were sent at least one working day before the scheduled interview date. Whenever possible, we complemented verbal data with archival data (Patton 1990). Archival data consists of, e.g., website information, program brochures, E-mail correspondence as well as blog entries or articles in practitioner journals.

1.3.3. Data analysis

The starting point of this study was to investigate the phenomenon of patent-based investment funds and to gain a better understanding of their activities. Data was ordered according to the investment process step described in literature (Gredel et al. 2012; Rüther 2012) using the coding software MAXQDA. Comments on and descriptions of fund activities were extracted from every single interview or data source and were compared across interviews to identify common characteristics. In a second step, we linked these activities to the knowledge spillover process and knowledge filter model described in the literature. We found that fund's approaches could be clustered into four categories which show specific common characteristics. As a result, we developed a classification of distinct commercialization strategies.

Following this analysis, the question of which invention characteristics could be linked to these strategies emerged as a dominant topic. To identify these characteristics, we started with open coding and constantly went back and forth between the original data, evolving concepts and extant literature on asset characteristics (Silverman 2006; Miles and Huberman 1994). Finally, we aggregated our findings to propose a combination of specific dimensions per characteristic which determine the suitability of an invention for each of the described commercialization strategies.

We note that our process was inductive and that we identified literature appropriate for framing our data and findings in the process of this iterative data analysis approach (Souitaris et al. 2012; Miles and Huberman 1994). We did not have the intention of testing findings already in the literature. Instead, our aggregated findings refine and complement existing literature and may guide future studies in this field (Cunningham et al. 2016; van de Ven 2007). Striving for

a compelling and comprehensible presentation of the qualitative results, we use both "power quotes" illustrating our arguments in the text as well as "proof quotes" that further underline our points and show their prevalence (Pratt 2009, 2008).

1.4. Results and discussion

We present our findings on our first research question and describe activities of patent-based investment funds and their role in the knowledge spillover process. In doing so, we concentrate on characteristics common to the types of funds explored. Subsequently, we focus on dissimilarities between funds' business models and propose a typology of distinct commercialization strategies. These strategies determine the degree of value creation exerted by these funds and indicate to what extent they contribute to the transformation of invention to innovation. Second, we develop a set of invention characteristics and explore how each of the proposed commercialization strategies relates to specific dimensions of these characteristics.

1.4.1. Activities of patent-based investment funds and their role in the knowledge spillover process

1.4.1.1. Common activities of patent-based investment funds

We describe common activities of patent-based investment funds in four steps: Origination, Selection, Development and Exit. This builds on prior findings on the process of patent-based investment funds (Gredel et al. 2012; Rüther 2012).

First, commercially viable patents are actively originated out of the aggregate stock of knowledge. Sources of valuable patents or patentable inventions are typically universities or other public research institutions as well as companies which do not commercialize all inventions stemming from their corporate R&D themselves. By establishing strong relationships and trust with these IP generating institutions and individual inventors, funds get access to patents or patentable inventions.

> "You have to have the network, the connections, people have to trust you so that they open up the doors and […] say all right, […] take a look at our IP assets and tell us how to do it." (#21)

Some funds even use proprietary sources of inventions which they establish through contractual and exclusive relationships with knowledge producers. Thereby, patent-based investment funds can penetrate institutional knowledge filters on the individual level, such as the attitude towards exploiting the invention and the perceived feasibility (Guerrero and Urbano 2014; Carlsson et al. 2009), as well as on the organizational level, such as resource and competency constraints of universities or companies (Guerrero and Urbano 2014; Gredel et al. 2012; Benassi and Di Minin 2009). Because patent-based investment funds look for both patented and patentable inventions, it should be noted that these filters can also emerge after IP protection is granted. This contrasts with the spillover process depicted by Guerrero and Urbano (2014) or Carlsson et al. (2009).

Subsequently, patents or patentable inventions are selected according to legal, technological and commercial criteria (Gredel et al. 2012). To do this, funds employ managers who have industry and commercialization expertise as well as experience in selecting promising inventions. Besides, they leverage their networks to include deal-specific experts and make use of proprietary resources to assess patent characteristics.

> "We are doing the initial opportunity scan and initial opportunity identification algorithmically. […] we access technical expertise and market expertise to the extent we can […], leveraging our network of technology experts […] and as we get into the opportunity, we use to bring onboard technical specialists." (#15)

As a result, patent-based investment funds facilitate the separation of knowledge from potentially economically useful knowledge (Hayter 2013; Carlsson et al. 2009; Acs et al. 2004). They can thereby compensate for the resource and competency constraints of universities, research institutions and corporations.

After promising patents or patentable inventions have been selected, the commercialization phase starts. The fund acquires or gains control over the selected patents or patentable inventions and the patent owner transfers the commercialization right to his or her invention to the fund either through a sale, where the IP is fully assigned to the new entity, or through a license, where only the commercialization right is transferred. The fund structures the deal through a combination of upfront fees, royalties and – in the case of start-up creation – equity shares. This sets incentives for the future alignment of the interests of involved parties. The underlying technology is then further developed until it reaches a stage where it can be successfully exploited (Festel 2013; Gredel et al. 2012; Pries and Guild 2007). Mode and activities in this stage depend on the commercialization strategy chosen by the fund. Independent of the pathway, however, the goal is to decrease technological risk and to bring technologies closer to the product market – either by embedding them in an industrial company or by creating a new stand-alone company. Thereby, funds foster the development of an invention into a revenue-generating or productivity-enhancing innovation. Through the investment in this early technology development patent-based investment funds provide resources to overcome another filter in the commercialization process: the financial gap between basic research and the product development based on a prototype and validated business plan (Bradley et al. 2013; Auerswald and Branscomb 2003).

Finally, the fund exits the investment. Therefore, funds again use their network and industry knowledge to get access to parties that might be interested in the technology. "[…] for the exit, you need industry connections, you need to know potential licensors" (#14). Timing and mode of the exit depend on the commercialization strategy.

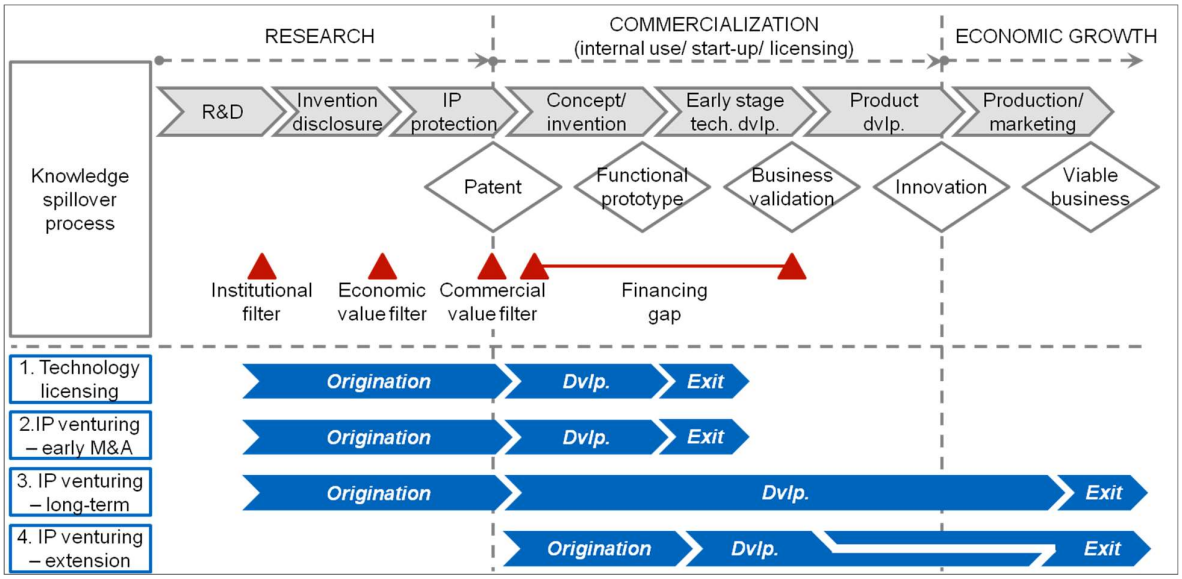
1.4.1.2. Classification of commercialization strategies of patent-based investment funds

When matching the described activities to the stages of the knowledge spillover process as detailed in the theory section of this paper, it becomes apparent that fund models can be differentiated by the commercialization mode as well as by the locus and length of their development activities. Based on the analysis and comparison of fund models discussed in our interviews we present a classification of four distinct commercialization strategies, which are

illustrated in Figure 6: "Technology licensing", "IP venturing – early M&A", "IP venturing – long-term incubation" and "IP venturing – extension". Further evidence is provided in Table 3.

Figure 6: Classification of commercialization strategies of patent-based investment funds

Source: Own illustration



Funds active in *"Technology licensing"* acquire or gain control over patents and their underlying technology in an early development stage and aim to commercialize them through licensing the IP and transferring the technology. As incumbents are often unwilling to in-license nascent technologies due to the risk and uncertainty associated with that early stage, the technology is developed until there is an inflection point in value and large existing companies take over. This inflection point is often reached after a proof of concept or a prototype is available, where the uncertainty about "the readiness of the technology for product application" (Pries and Guild 2007, p. 321) for potential acquirers of the technology is sufficiently decreased.

> "[...] if you try to license [the invention] but haven't developed a working model of the technology you won't get a lot of value from it." (#17)

The development stage is therefore an important aspect of the additional value funds provide and a prerequisite to enabling technology transfer (Festel 2013; Pries and Guild 2007). Funds that follow the technology licensing route have internal capabilities to do this development or engage external service providers on a project basis. Typically, they cooperate with the inventor(s) in this stage (Gredel et al. 2012). The exit is constituted through a license or a sale to an existing company. In contrast to patent licensing, the technology licensee does not only get access to the legal right of practicing what the patent describes, but a technology transfer takes place (Krech et al. 2015).

> "When you [...] only transfer the patent without the know-how or the trade secrets behind it, you lose a lot. You basically only have the tip of the iceberg and the acquirer or the licensee of the technology is going to miss all of this know-how." (#8)

The IP is therefore packaged with the underlying technology in form of know-how, user manuals or people in order to enable the licensee to continue the development and to use the technology in a product. Funds applying technology licensing are therefore active in the "markets for technology" instead of the "markets for patents" (Fischer and Henkel 2012, p. 1531).

The alternative mode used by patent-based investment funds is the commercialization of the technology via start-up creation. The term "IP venturing" therefore describes the creation of a new start-up around a given technology and the patents that protect it. It refers to the activities of a fund which is active in the setup of a new venture and which recruits a management team that takes over development and commercialization tasks from this point on. Patent-based investment funds also provide primary investment both in the pre-incorporation stage as well as in the newly created start-up. The fund exits the investment through a trade sale or an IPO. The start-up creation pathway is related to the pre-seed stage of venture capital. However, it can be differentiated from the traditional venture capital model, as the basis of their investment is intellectual property as opposed to already created early-stage firms:

> "[…] these are IP funds as opposed to venture capital funds. [...] they are investing in purely intellectual properties. They're so early stage that there is no company that venture capital would invest in." (#21)

Strategies can be differentiated based on the length of funds' development activities along the knowledge spillover process and the exit.

The strategy *"IP venturing – early M&A"* is based on the previously described incubation logic where the technology and the patents around it are transferred to a new start-up. When comparing the starting point and length of the development phase in the knowledge spillover process with those of "Technology licensing" depicted in Figure 6, both strategies look very similar. The technology is developed until an inflection point in value is reached at which the investment can be exited. However, the locus of development is different, as the management team of the newly created start-up is in charge. The exit takes place through an early trade sale of the new company at a stage where the technology is more advanced but cash flows are still missing.

> "A lot of M&A, certainly in life sciences and technology, happens before […] anybody's even gone to market. Safety trials in pharma are often the point where you acquire. You don't have drugs, not been approved, not in the market, but it doesn't kill people and it seems to work." (#11)

This corresponds to the matching mechanism described by Ghio et al. (2015), where new ventures which exploit knowledge spillovers are acquired by incumbents who eventually bring the product to maturity (Lehmann et al. 2012). The exit thus takes place in the "markets for technology" (Fischer and Henkel 2012, p. 1531).

The strategy *"IP venturing – long term incubation"* can be differentiated from the prior strategy as it aims to create a stand-alone, cash-flow-producing new company which commercializes the technology. In contrast to "IP venturing – early M&A", the fund accompanies the new company along the entire process from an early stage invention to innovation.

> "You build a business around a new technology, so at the end of the day you're not licensing technology per se; you're selling the product." (#13)

The fund is often also involved in later stage investment rounds and exits the investment either through a later trade sale or through an IPO. The exit takes place in the M&A or equity markets.

The fourth strategy has been identified as *"IP venturing – extension"*. This strategy focuses on extending the use of already existing IP and is typically based on more mature IP which stems from existing large companies as opposed to universities. The added value provided by funds supplies financing for the development of alternative applications for a given technology which is already commercialized or which failed in the originally intended application.

> "[…] thinking creatively about your IP in other applications suddenly gives you a totally different business model." (#11)

A typical example can be found in the area of pharmaceuticals where patent-based funds might develop a molecule for alternative indications and gain approval for it.

> "[…] because it's so hard to get something approved there is a trend towards trying to be very creative with drugs that have already been approved to find other uses for them, because you've already spent so many dollars getting through the regulatory hurdle." (#11)

Analogous to the prior IP venturing strategies, the investment can be exited through an early trade sale after a certain milestone has been achieved or the fund can build up a stand-alone, cash-flow-producing company and exit the investment through a late trade sale or IPO.

Our findings show that despite common characteristics and activities of patent-based investment funds four distinct strategies to commercialize patents and their underlying technologies can be differentiated. Funds often specialize in one strategy but may also use the entire spectrum of commercialization approaches.

Table 3: Classification of commercialization strategies of patent-based investment funds

	1) Technology licensing	2a) IP venturing – early M&A	3a) IP venturing – long-term incubation	2b/3b) IP venturing – extension
Length of development	• [Developing the technology] is really important […]. What people want is at least a demonstrator that the IP works. (#10) • [The fund is] investing in the proof of concept, the development, the prototyping [...]. (#21) • [...] we know that [the technology] needs a bit of refinement. The model is about asset enhancement, asset value enhancement. Before the enterprise creation, or cooperating enterprise creation with sales etc. It is just about the asset. (#11) • [...] we didn't have prototypes, and so we specifically created a fund that would try to give the professor enough money to create a prototype that we could then later take to industry and say, here is technology along with the patent to license. (#14)	• [...] we develop the IP until we bring it to the point where someone else takes over. We never bring the product to market, [...] we start at an early development stage and try to finance one value-enhancing step in the development. (#12) • Let's do the initial part of the proof of concept, the proof of principle and then get it to a stage where you see this inflection point in value, which is where [...] we would exit at that point in time. (#21) • Start-up building around IP happens often in Life Science, where you create little speed boats which push the development and where the later clinical phases are then taken over by large pharma companies. (#5)	• You build a business around a new technology, so at the end of the day you're not licensing technology per se; you're selling the product. (#13) • The other model is that we invest in a company with a larger pipeline. [...] Making the company really large is of course a completely different model. (#12) • Funds with incubation strategy are often very long term, [...] funds that have a twenty year life, which develop the technology, do research and ultimately try to make a product around it. (#5) • We'll create an operating company and hopefully that will get through to the market. (#11) • […] building companies with significant numbers of employees, production facilities and so on to create operating companies. (#11)	• […] does it do anything else other than the thing it was originally developed for? [...] That approach is more about product life extension – […] repositioning, re-protecting, and creating more value from an existing IP. (#11) • And thinking creatively about your IP in other applications suddenly gives you a totally different business model. You don't think of it as platform, but it can be. (#11) • We were all about what we called business innovation, the idea of taking a technology that was created for one thing, and finding a new application for it. (#9) • […] working with multi-nationals to thin out technologies which, for one reason or another, never made it to the market or failed in the market on the large multi-national platform. (#11)
Locus of development	• [The fund is] doing the development so they're spending their own money, their own lab and resources, and their own people are doing that. (#21) • I have to identify a bunch of technologists [...] to build a proof of concept or a prototype. (#13) • What we have done is find joint development agreements, i.e. contractually specified roles of different parties. (#15)	• So what you need to create is what I would call a venture builder organization, it's not so much teaching the researcher to be an entrepreneur but building a team around the researcher, and then if you can create that team [...] you also request that the researcher stay with it for a while. (#17) • [I]f the commercialization path is a start-up company, you can give the inventor shares of the company and have them involved from a technical standpoint or a consulting standpoint. (#14) • [The fund] had access to a cadre of entrepreneurs that they could call on. They knew enough people that were willing to do that. So they would set up the company with people that they know and were in their networks. (#16) • In the case of the pharmaceuticals, to give you an example, [...] you cannot do it in house, it has to be done by a company which has got everything and in terms of resources take it forward. (#21)		

Table 3: (continued)

	1) Technology licensing	2a) IP venturing – early M&A	3a) IP venturing – long-term incubation	2b/3b) IP venturing – extension
Mode of exit	• Packaging is a combination of patents with the underlying technology, with skills, with the product implementation, and with the release notes or supporting management expertise; it creates a value proposition to an ultimate buyer or licensor. [...] Most companies that try to be technology licensors cannot package something that's compelling enough or a customer would want to pay real money for. (#13) • [...] because of our business and because of what we do, we know who's going to license this [...] so for us it's about plugging something that we absolutely know into something else that we absolutely know. (#11) • If you only transfer the patent without the know-how or the trade secrets behind it, you lose a lot. You basically only have the tip of the iceberg and basically the acquirer of the technology or the licensee is going to be missing all of this know-how. (#8) • You do a technology license, you don't do just the patent license, you license the entire technology. So patents plus know-how. (#8)	• A lot of M&A, certainly in life sciences and technology, happens before anyone has made any money and sometimes it's happened before anybody's even gone to market. (#11) • Particularly with pharmaceuticals in the US the expense to develop a drug all the way, go through the trials, get the FDA to approve it, is really high, and a market has developed where you can sell along the way before you finish. (#17) • [...] mapping the exit from day one, understanding what's required, talking to the exit partner and understanding what they need, identifying the gap in the pipeline and playing directly into that. (#11) • Technology transfer businesses pretty much try and get out of building companies as soon as possible: put minimum infrastructure, minimum prototypes and they try and exit as fast as they can. I would call that enhanced licensing. (#11)	• Typically [we invest in all investment rounds up to an exit, either via IPO or a trade sale]. (#10) • The technology transfer organizations [...] think about building companies. They think about IPOs. (#11) • They not only want to exploit the patent but want to build up companies and products; they want to stay invested in those new companies on a long term basis. (#4) • It's very analogous to the venture capital situation. (#4)	*Analogous early M&A or long-term incubation*

1.4.2. Invention characteristics for different commercialization strategies

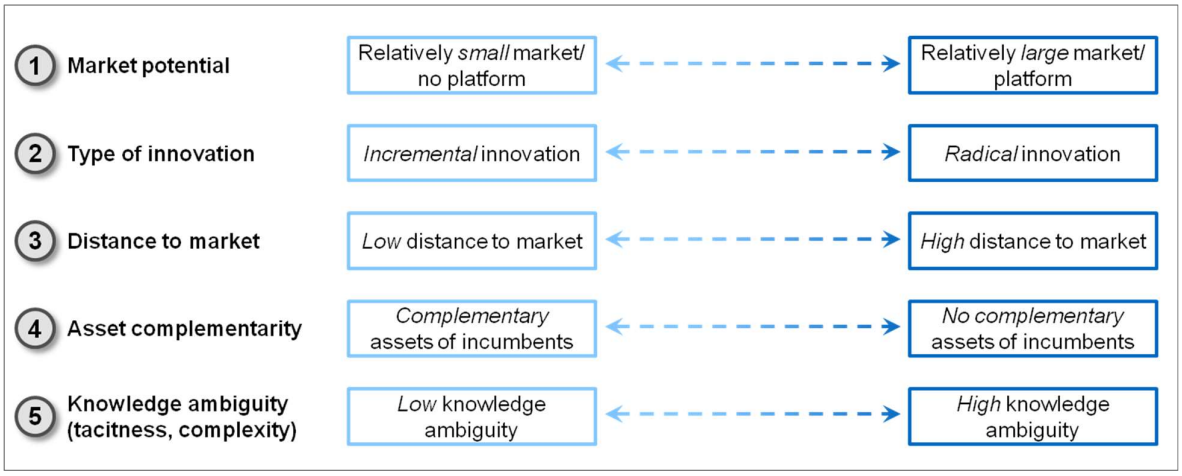
It became apparent during data collection and analysis that certain commercialization strategies are linked to specific invention characteristics. We therefore explore in more depth the invention characteristics which funds assess to select patents or patentable inventions given their commercialization strategy or – in the case where more than one strategy is applied – how the commercialization path is chosen given certain asset characteristics. We first introduce these characteristics and then propose typical dimensions of each characteristic for the four commercialization strategies described in the previous chapter. We also shed light on implications for investment characteristics such as investment horizon or investment size.

1.4.2.1. General and strategy-specific invention characteristics

The first characteristic, which is considered crucial for all commercialization strategies applied by patent-based investment funds, refers to the strength and breadth of patent protection. The existing literature states that IP protection favors the commercialization of a technology in general (Eckhardt and Shane 2010). In the special context of patent-based investment funds, this characteristic is a "conditio sine qua non" (#12). Nevertheless, it was often stressed in interviews that patents must present valid and enforceable claims. They should also be able to provide exclusivity without the possibility of an easy workaround. Through these characteristics, unwanted automatic spillovers of knowledge or the duplication of an innovation through a workaround without the appropriation of returns for the patent owner can be avoided.

Beyond this general aspect, each commercialization strategy requires certain invention characteristics: "The determination of which mode of commercialization makes sense is based on what the intellectual property is" (#14). Based on our results from qualitative data analysis matched with the existing literature we propose five distinct characteristics and categorize them along dimensions as depicted in Figure 7.

Figure 7: Strategy-specific invention characteristics



- The **market potential** refers to the relative size of the market of the envisaged application(s) of the technology (Eckhardt and Shane 2010; Shane 2001a). It also includes an assessment of whether the technology is a platform technology that can be applied across different industry verticals.
- The **type of innovation** describes whether the innovation resulting from a given technology is an incremental or a radical innovation (Block et al. 2013; Eckhardt and Shane 2010; Arrow 1962). In addition, the degree to which the relationship between patent and product is discrete, i.e., the envisaged product is closely described by the patent, plays a role.
- The **distance to market** includes the time and investment needed for the development of the technology (Eckhardt and Shane 2010) up to the point where the technology is sufficiently de-risked that incumbents are willing to incorporate it or where a market-ready product exists. The maturity of the technology at the time the fund takes over also plays a role in the specific context of patent-based investment funds.
- **Asset complementarity** describes whether complementary assets for bringing the envisaged innovation to market are available at existing industry players. This characteristic also implies the importance and concentration of these assets as well as the costs of duplicating them (Eckhardt and Shane 2010; Gans and Stern 2003)
- **Knowledge ambiguity** refers to the importance of tacit knowledge, the degree to which it can be codified and the complexity of the technology described by the patents

(Eckhardt and Shane 2010; van Wijk et al. 2008; Simonin 1999). The importance of tacit knowledge can be influenced by industry-specific factors, such as the availability of experts in the market, which have the know-how to read and understand codified knowledge.

1.4.2.2. Specifications of invention characteristics for different commercialization strategies

Technology licensing

For a technology which is envisaged to translate into an innovation with a relatively small market or a technology which cannot build a platform for application in different verticals an early integration into an existing company through licensing is suggested. The typical innovation type for this commercialization strategy is an incremental innovation. This is closely linked to the next two characteristics: For technology licensing, a low distance to market is favorable. 6-18 months are typical to cross the concept and early technology development stage of such an invention and to reach the inflection point in value. For a longer development time, the governance structure of contracts with external service providers and/or the inventor (group) is considered less suitable and more expensive than the structure of a newly created start-up.

Moreover, the availability of complementary assets favors the use of markets for technology and therefore commercialization via technology licensing. Entering the product market could require a duplications of these assets, which is very costly (Gans and Stern 2003). The criterion concerning the availability of complementary assets has been mentioned in the literature (Eckhardt and Shane 2010; Gans and Stern 2003). When considering the special context of a patent-based investment fund, however, it seems to be particularly pronounced:

> "[…] potential companies who would be interested in this intellectual property are not willing to buy it before they have proven that it's really applicable in their product." (#13)

Successful exits in technology licensing share the characteristic that the licensee is known from the beginning and that the development takes place in cooperation, i.e., the technology is tailored to the existing assets and requirements of the future licensee.

> "[…] it is the opposite of 'if we build it they will come'. You need to build it with the customer so that they get what they want and then you will get royalty on it." (#11)

Table 4: Invention characteristics of Technology licensing

1) Technology licensing	
Relatively small market	• International scale [for IP venturing] versus local market relevance [for licensing]. (#11) • If it doesn't give you a new business then you would like to fit it to an existing company with existing infrastructure (#18)
Incremental innovation	• [...] typically, a continuous innovation invention - you can plug it into a license, a traditional license because there's already a product, there's already an entity which is doing it. (#21) • [If the technology] is not so cutting edge but it's new for them, it doesn't need a start-up; an established company can utilize the technology. (#20) • [...] if your IP reads diffusely or indirectly to product, then licensing may be a better approach. (#11)
Low distance to market	• The holding period for that kind of investment [...] would be somewhere in the six month to a year range where, you're taking the risk and then going out and doing the marketing, prototyping, productization and selling it. (#21) • The problem is that the development is very expensive when external technology experts are doing the development. (#12) • [...] where the development process will take three to five years time and be $50-100M in investment. You cannot do it in house; it has to be done by a company which has got everything to take it forward. (#21)
Complementary assets of incumbents	• I'm just giving this to an entity which already has the wherewithal to take it to the next step as they already have sales, distribution, marketing channel, they know how to do the proof of concept, I'm handing it over to them. (#21) • Potential companies who would be interested in this intellectual property are not willing to buy it before they have proven that it's really applicable in their product. (#13)
Low tacit knowledge/ low ambiguity	• I have a good example of one deal that I am working on right now where the inventor isn't there and we have the secondary challenge of tech-transfer because the people that are most knowledgeable about the technology are not available immediately. It's difficult to communicate that value to the licensee or the acquirer. (#20) • You don't want to license IP that is tied to a particular person. You find the IP and want it to be transformational enough so that you get a hand off and then you can hand it off again. You don't want your licensee to say, oh, can I talk to the inventor? (#18) • The technology license requires that inventor to be involved in the ultimate transfer of the technology to the ultimate licensee, and it's really hard to do that. (#13)

The exit through technology licensing requires packaging and transferring patents plus the underlying codified and un-codified knowledge to the licensee. Therefore, technologies with little tacit knowledge and relatively low complexity are better suited to licensing. In the case of high knowledge ambiguity, strong involvement of the inventor (group) as bearer of the

tacit knowledge is considered necessary both during development and exit (technology transfer) (Gredel et al. 2012). In an extreme case, this might even imply that the "inventor needs to be willing to possibly become an employee, at least five years, of the companies that are looking to license his technology" (#13). Managing this as a fund playing between the inventor and the ultimate licensee is perceived as a major challenge in technology licensing. This challenge is even more pronounced when a truly global network of researchers is leveraged to source IP and the transfer takes place across regions.

These asset characteristics represent rather specific requirements for the suitability of technology licensing through a patent-based investment fund. The impact on investment characteristics is twofold. On the one hand, they imply a relatively short holding period (6-18 month) and a smaller investment size, as well as a relatively lower risk/return per deal compared to the venture creation pathways. On the other hand, technology licensing is considered as a more opportunistic possibility to commercialize IP.

> "[…] what we do is very opportunistic. We will see something and we will only get involved when we can actually foresee from the beginning with almost 100% certainty [that we] have a buyer." (#11)

IP venturing – early M&A

In contrast to technology licensing, a relatively large market is required for building a start-up. The envisaged innovation is more radical and the distance to market is especially high. If time and the investment requirements to reach the inflection point in value are high, the governance form of a start-up is considered more suitable for development. Instead of developing the technology internally or externally through service providers, an entrepreneurial team, highly incentivized through shares and intrinsic motivations and therefore more resilient to push backs, drives the technology forward:

> "[In] a new company […] people have that passion for this strange new thing that may or may not work. And they create almost a little cocoon of believers around that idea." (#10)

Typical examples of a long distance to market are in the pharmaceutical industry: "If you are investing in life sciences you have to [have] patient money where you can wait for seven to ten years before your exit happens" (#21). In such a case, funding the development for technology licensing internally or externally through technology experts would imply very high costs without an optimal alignment of interest.

Table 5: Invention characteristics of IP venturing – early M&A

	2a) IP venturing – early M&A
Relatively large market	• And there is the other way where you see that nothing like that exists on the market. And that there is a market large enough for a start-up. (#3) • Then you analyze how big the market is and what that means for pricing and reimbursement. And how do I need to develop the technology to target this market potential. (#12)
Radical innovation	• If the IP is revolutionary then large companies often have a big problem incorporating it into their large companies, and they normally fail. So it's much better starting a new company where people have that passion for this strange new thing that may or may not work. And they create almost a little cocoon of believers around that idea, and sometimes it works and often it doesn't work, but it needs a separate entity away from large companies. (#10) • Start-up building around IP happens often in Life Science [...] but also in electro mobility, battery technologies. Where you see very new and disruptive technologies being commercialized through start-ups. (#3)
High distance to market	• Just like you start a company you have to start a project to commercialize anything, and so even internally the company's got to go through an internal venture builder stage and go through all the same steps, and it's more expensive to do it inside of a company, actually. (#17) • [...] where the development process will take three to five years time and be $50-100M in investment. You cannot do it in house; it has to be done by a company which has got everything to take it forward. (#21) • The second issue is the cost involved with bringing in early stage technology that you have [...] to invest in developing it. A start-up has that model anyway so their structure is set up to develop a technology. (#18)
Complementary assets of incumbents	• The capital requirements of pharmaceutical development are so large that there's no option, it has to be sold to a pharmaceutical company, they're the only ones who can afford the final human studies that are required for regulatory approval. (#19) • If it works it becomes interesting for a larger player. Start-up building around IP happens often in Life Science, where you create little speed boats which push the development and where the later clinical phases are then taken over by large pharma companies. (#3)
Tacit knowledge/ high ambiguity	• Most innovative novel technologies, because they are innovative and novel, you can't just hand it to a team of clever people and say, get on with it. Because even those clever people weren't around when it was being dreamed up, and you know, don't know the details of why it's so clever. (#9) • A start-up needs to conserve cash, so the last thing that the start-up wants to part with is cash. The thing that it has inexpensively is shares. […] You really want to align the interests of the company with the interests of the person that you get the IP from, so that they're interested in making the company successful. Which also means a continued help with making the IP valuable.(#10) • Commercializing the IP without the inventor will work after some while, when the knowhow is transferred to the new entity. (#4)

Like technology licensing, the exit takes place in the market for technology. An incumbent acquires the new venture at an early stage and takes the technology to the stage where a marketable product can be produced and sold. Therefore, the suitable complementary assets are available in the market and should not be duplicated (Gans and Stern 2003). The higher the ambiguity of knowledge is, the better suited the patent or patentable invention is for start-up creation as commercialization pathway exerted by a patent-based investment fund. This is because the governance form that comes with a new venture is more adequate to deal with high knowledge ambiguity. First, depending on the degree of tacit knowledge that lies with the inventor(s) of the technology, the degree of inventor involvement can be steered through his or her role in the venture, ranging from an operative function to a non-executive position e.g., as scientific advisor. Suitable incentives through equity can be adjusted respectively and typically range between ~5-20%. Second, in the exit event not only is the IP transferred but the entire entity which now possesses all the tacit knowledge built up during the development of the technology is incorporated into the acquiring company.

These characteristics imply that investments are longer (~5-10 years) and bigger in size than in the licensing scenario because of the long distance to market. However, they also allow for a bigger return upside, as would venture capital.

IP venturing – long term incubation

If the market potential is very high and provides a large enough opportunity for a new business, or if the technology provides a large enough platform, the IP is more suitable for a stand-alone company:

> "It either has to be a very specific invention with a large market to be a start-up company, or a very broad technology that can be used in multiple markets to be a start-up company." (#14)

Potentially large future cash flows must compensate for the high investment and risk associated with this strategy. Even more pronounced than for the early M&A strategy is the criterion "radicalness" of the invention:

> "If the technology is very cutting edge, the financing and the structural requirements to have that technology commercialized are a better fit as a start-up." (#20)

This finding provides evidence for the suggestion brought forward by Block et al. (2013) that start-ups are more likely to exploit knowledge spillovers resulting in radical innovation and more productive in their efforts than established firms. Furthermore, the discrete relationship between the patent (portfolio) and the product is relevant when the goal is to establish a stand-alone, cash-flow-producing company: "If I have a patent that reads directly into a product, I could sell the product" (#11). Like the early M&A strategy, distance to market can be high. It can take up to 20 years until the innovation stage is reached and cash-flow is produced. The most important differentiating feature to the prior strategy is that the technology is so new that there are no complementary assets of incumbents available. If incumbents' assets do not provide an advantage in commercializing the new technology, a start-up going all the way to the product market can be the best solution (Gans and Stern 2003). As explained earlier, a start-up can deal with high knowledge ambiguity. Tacit knowledge that lies with the inventor(s) needs to be transferred only to the new venture. Inventor involvement is typically considered helpful in the first 2-3 years after the creation; afterwards the new company is expected to have incorporated and accumulated all knowledge necessary to drive commercialization forward.

Investment characteristics of the long-term incubation strategy are similar to those of venture capital. The key difference is that the initial investment is based on IP and is therefore much more in an early stage. This implies that the holding period required for accompanying the development, at least up to the point where the transfer to innovation is accomplished, is very long (15-20 years). Similarly, total investment is comparably high as the fund needs to participate in large later stage investment rounds in order to avoid dilution. In total, this strategy is associated with the highest risk/return compared to alternative commercialization efforts.

Table 6: Invention characteristics of IP venturing – long term incubation

	2b) IP venturing – long term incubation
Relatively large market	• [In a start-up] it might be a platform technology that they take to market. (#21) • If I had the choice of picking which one would go to start ups and which ones would not you would want something that is more of a platform technology. It has a number of things involved and you have a number of pathways to go forward with it. (#21) • It either has to be a very specific invention with a large market to be a start-up company, or a very broad technology that can be used in multiple markets to be a start-up company. (#14)
Radical innovation	• If the technology is very cutting edge, the financing and the structural requirements to have that technology commercialized are a better fit as a start-up. (#20) • A disruptive innovation is much more well-suited for a start-up. (#21) • If I have a patent that reads directly into a product, I could probably sell the product. (#11)
High distance to market	• For a start-up really what I would say is that it's patient money, so you have to be very patient for that start-up to be exiting and being successful (#21) • If you're finding very, very early stage IP from an institution, I think the pay-out is just very, very long. [...] You may make money 20 years from now or 10 years from now. (#18) • The funds with the incubation strategy are often very long term, [...] we see funds that have a twenty year life which develop the technology, do research and ultimately try to make a product around it. (#5)
No complementary assets of incumbents	• [For very disruptive technologies] large industry partners do not have the processes to find them interesting. (#3)
Tacit knowledge/ high ambiguity	• […] lot of the value of the IP is actually not in the patent, or not the publications, but it's all the green finger staff, all the know-how, and the stuff that is not written down. Which is know-how that circulates round that group of researchers that you want to catch. (#10) • [The importance of inventor involvement] fades away over time. So in the beginning I think it is very important to have [...] somebody from that [inventor] group with a detailed understanding. All those sort of magic tricks that they develop in a group of researchers. [...] When we are really doing the early stages of the project, they're absolutely critical. Let's say for the first two or three years, but then there ought to be enough knowledge that gets created in the company itself, so that they don't have to have that umbilical cord back to their university group anymore. (#10) • I see the inventor is helpful usually for one year, maybe two years beyond the initiation of the commercialization attempt, but rarely is influential after that. (#19)

IP venturing – extension

In general, the asset characteristics for the IP extension strategy largely correspond to the early M&A and long term incubation strategy, respectively. The existence of complementary assets determines the length of the development and when the exit takes place. The crucial difference from the earlier-mentioned strategies in terms of asset characteristics is that the IP, which the fund acquires or gains control over, is more mature and it has already been proven that the technology per se is working. Typically the concept phase is already done and the IP is well packaged with study results, regulatory approvals and concept work achieved so far.

With regard to investment characteristics, the described features make the IP less risky and more valuable, i.e., the initial investment is higher.

> "I'm often deploying much more significant amounts of money [...] and a lot of that is to do with building companies with significant numbers of employees, production facilities and so on to create operating companies." (#11)

1.5. Implications and conclusion

In this paper we investigate the new and under-researched phenomenon of patent-based investment funds which are active in the important process of transferring inventions to innovation. We explore common characteristics of patent-based investment funds and their role in the knowledge spillover process. We find that these funds can be active in the entire knowledge spillover process and that they decrease knowledge filters that might otherwise impede the commercialization of knowledge. We therefore introduce patent-based investment funds as new intermediaries in the market for technology, which catalyze the invention-to-innovation transition. We also propose a classification of commercialization strategies which can be differentiated by mode, locus and length of the development phase: "Technology licensing", "IP venturing – early M&A", "IP venturing – long term incubation" and "IP venturing – extension". We find that specific invention characteristics can be associated with these strategies. Different dimensions of the five categories "market potential", "type of innovation", "distance to market", "asset complementarity" and "knowledge ambiguity" determine the suitability of a technology for one of the described commercialization strategies.

These results have both theoretical and practical implications. First, by gaining a better understanding of the activities and role of patent-based investment funds, we contribute to the knowledge spillover theory of entrepreneurship as well as to the literature dealing with patent and technology intermediaries in general and patent-based investment funds in particular. Second, our findings with regard to invention characteristics and their suitability for specific commercialization strategies adds to the respective literature streams in entrepreneurship and technology transfer research. Moreover, this study has interesting practical implications for

fund managers and managers dealing with external patent exploitation in general. After discussing these implications we conclude this paper with limitations and possibilities for further research.

Theoretical implications

We are the first to introduce patent-based investment funds as facilitators in the knowledge spillover process (e.g., Acs and Sanders, 2012). Our findings contribute to the knowledge spillover theory and the knowledge filter model. Patent-based investment funds rely on the principle acknowledged by the KSTE that the commercializer is not necessarily the knowledge creator (Ghio et al. 2015; Block et al. 2013; Acs and Sanders 2012; Braunerhjelm and Svensson 2010; Acs et al. 2009a). This division of labor between inventor and commercializer is an important assumption of the KSTE (Ghio et al. 2015; Acs and Sanders 2012), but its exact mechanism has not been investigated from the point of view of an intermediary (Acs and Sanders 2012). Our investigation starts filling this gap in previous research by showing that patent-based investment funds as a special type of technology intermediaries drive forward the commercialization of a technology from the point at which they acquire or gain control over patents or patentable inventions and bear the financial risk of commercialization. Our findings provide evidence that patent-based investment funds can take over or enhance the entrepreneur's function of "entrepreneurial absorptive capacity" (Qian and Acs 2013) which implies understanding new knowledge, recognizing its value, and commercializing it. However, it should be noted that the division of labor between knowledge creator and commercializer is not always straightforward. When knowledge ambiguity is high, lines can be blurry and inventor involvement becomes critical.

Moreover, our insights shed light on how these funds can address and eliminate knowledge filters in the knowledge spillover process, such as institutional filters, as well as competency and financial constraints (Guerrero and Urbano 2014) by actively originating, selecting and investing in technologies protected by intellectual property rights. In addition, the investigation of patent-based investment funds provides empirical evidence of the importance of networks in overcoming knowledge filters in the knowledge spillover process (Hayter 2013).

Funds build up networks with inventors to effectively source patents and patentable inventions. They also maintain and leverage a network of industry and technology specialists to separate knowledge from economically useful knowledge and to search for potential licensees or acquirers of the technology. As a result, patent-based investment funds can create "new opportunities in a Schumpeterian sense" (Ghio et al. 2015, p. 14) by exploiting otherwise unrecognized opportunities.

Our classification of commercialization strategies contains the entire spectrum of patent-based investment funds' business models contributing to the transition from invention to innovation with varying degrees of value-add to the underlying technology. Whereas many contributions to the KSTE focus on start-ups as vehicles exploiting knowledge spillovers (Block et al. 2013; Acs and Sanders 2012; Braunerhjelm et al. 2010), the recent literature on patent and technology intermediaries in general and patent-based investment funds in particular is limited to research on funds following the licensing route (Krech et al. 2015; Gredel et al. 2012; Kelley 2011; Wang 2010; Benassi and Di Minin 2009). We combine these approaches and complement earlier typologies by shedding light on both start-up creation and technology licensing as commercialization paths (Carlsson et al. 2009). With regard to the start-up creation pathway, we moreover differentiate among three venturing strategies based on IP. We therefore also contribute to the recent literature on patent and technology intermediaries in general; we position patent-based investment funds as an emerging entrepreneurial financing model in the very early stages of technology development (Festel et al. 2015).

We propose a comprehensive set of invention characteristics whose dimensions determine the suitability of four distinct commercialization strategies. Thereby we add to a stream of entrepreneurship and technology transfer literature which tries to explain commercialization efforts and modes with the nature of a given technology (Block et al. 2013; Festel 2013; Festel and De Cleyn 2013; Eckhardt and Shane 2010; Shane 2001a; Henderson 1993). The case of patent-based investment funds provides a special condition for the commercialization of inventions as they are specialized players with experience in IP management and commercialization. These funds either choose the invention corresponding to their commercialization strategy or they choose the commercialization strategy corresponding to the invention characteris-

tics. We conjecture that in this context asset characteristics, as opposed to the entrepreneur's individual parameters, determine which commercialization strategy is most suitable. In addition, this context solves the question of whether "the existence of technological opportunities leads to firm creation or the need to create firms leads to the creation of technological opportunities" (Shane 2001a, p. 217). As patent-based investment funds actively look for existing technologies and consequently commercialize them, the founding of firms results from the development of the inventions, not the other way round (Shane 2001a). These characteristics make patent-based investment funds a suitable unit for investigating the link between invention characteristics and commercialization strategies. Moreover, our insights might not only be useful in the context of patent-based investment funds, but also for external patent exploitation conducted by knowledge creators, i.e., universities or corporations.

We provide supporting evidence for prior literature, arguing that radical innovations are more likely to be commercialized via start-up creation (Block et al. 2013; Shane 2001a). Moreover, our results show that technology licensing is not only a way to plug a technology into an incumbent for commercialization. Rather, the investment and effort to advance the technology through the concept and early technology development is an important aspect of this commercialization path by funds. Due to the unfavorable governance form of developing the technology within the fund or through external service providers, we propose that a low distance to market with relatively low time and capital requirements for this development stage is suitable for the licensing strategy. This aspect is new and refines the prevailing argument that licensing is likely in the case of high capital intensity (Eckhardt and Shane 2010).

Our insights on commercialization strategies and corresponding invention characteristics have implications on the funds' setup and investment characteristics. The investment in a new start-up created around patents is seen as more risky but with the potential of a very high payback, given the more radical nature of the technology, the time horizon, investment need and market risk. Technology licensing, on the other hand, is associated with a lower risk and return ratio. This is generally in line with Bray and Lee (2000) who find the average return for taking equity in an academic start-up is higher than for average licenses in the long term. However, we deepen our understanding of technology licensing in the special case of patent-based invest-

ment funds and find that very strong pre-conditions have to hold in order to make technology licensing through a fund a viable commercialization model. These pre-conditions include factors such as fully embedding the technology in the licensor's processes and tailoring it to existing assets as well as a very high level of the ability to codify the underlying knowledge.

Practical implications

Through introducing patent-based investment funds and adding to our understanding of how they operate to transfer invention to innovation, we present these intermediaries as potential cooperation partners for technology providers such as universities, research organizations and corporations. With an increased understanding of their business models, technology providers might become less reluctant to facilitate access to inventions and to enter exclusive partnerships with funds. Thereby, knowledge filters might be decreased in a more systematic way and commercialization activities might be increased.

Furthermore, this study provides relevant insights for practitioners in the field of patent-based investment funds as well as for managers active in external patent exploitation. Results are not only relevant for privately operating funds, but might also be interesting to university TTOs, public research institutions or corporations striving for external patent exploitation. They have important policy implications for these organizations. This is especially relevant for our insights into critical activities in the commercialization process: the decision to search actively for unused inventions instead of waiting for proposals, the need for investment also in the technology licensing scenario, or the active setup of new ventures using surrogate entrepreneurs. Last, the link we explore between invention characteristics and commercialization strategies should help commercializers of technology make better selection decisions.

Limitations and future research

Due to the qualitative method applied, our study is non-representative and results cannot be generalized. It is based on the experience of experts in the field of IP commercialization, early-stage technology investment and patent-based investment funds. Although we managed to collect insights on the entire spectrum of commercialization pathways employed in fund mod-

els and complemented our interviews with archival data, we focus on the point of view of a patent-based investment fund and put the technology that is commercialized at the center of our attention. Future studies should include other perspectives, including, e.g., the inventor or the final acquirer of the technology. This could help us better understand the motivation and reaction to incentives of the involved parties as well as the needs and preferences of companies incorporating technologies developed by patent-based investment funds.

Furthermore, future research should build on our insights regarding start-up creation with respect to the possibility of forming teams around IP and the use of surrogate entrepreneurs (Politis et al. 2012; Kassicieh 2011; Franklin et al. 2001; Radosevich 1995). Studies should focus in greater detail on resources provided by funds and on success factors with regard to the recruitment of management teams and the involvement of the inventor(s). This would further contribute to our understanding of set-up and structuring of the division of labor between inventor and commercializer.

Finally, future quantitative research should include performance variables in order to assess the actual success of commercialization projects through patent-based investment funds as well as ultimate returns for inventors and investors. This is particularly interesting for the technology licensing path where preconditions are found to be very specific. In the case of start-up creation, it would be interesting to explore survival rates and performance of start-ups created by patent-based investment funds as opposed to other start-ups. Future research should also test the impact of specific success factors on this performance. One success factor might be the appropriate selection of inventions for particular commercialization strategies using the proposed characteristics. This research will show whether and how private patent-based investment funds can sustainably contribute to the transformation of invention to innovation.

2. Essay 2: Business builders, contractors, and entrepreneurs – an exploratory study of IP venturing funds

Abstract

Despite the importance of investments in new technology-based ventures to foster entrepreneurship and growth, investors are often deterred by the riskiness of these assets. We investigate the phenomenon of intellectual property (IP) venturing funds which commercialize technology via start-up creation. We aim to answer the question of how funds' activities decrease agency risks and add value, eventually leading to a higher return. Our findings are based on six cases analyzed at the deal and fund level. We propose that IP venturing funds increase returns through active business building. In addition, we establish a dichotomy with regard to investment styles of IP venturing funds. In an opportunity-driven investment style, funds act as entrepreneurs and are compensated for opportunity recognition. In a technology-driven investment style, funds act as contractors, applying novel mechanisms to reduce agency costs and keep due diligence costs low. We contribute to knowledge of new investment models in entrepreneurial finance and how they manage agency risks. We also add to extant research on the entrepreneurial process and provide evidence of entrepreneurial resources as an eclectically sourced stock.

Keywords: pre-seed venture capital; IP venturing; patent-based investment funds; agency costs; opportunity recognition

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2.1. Introduction

The exploitation of inventions through the creation of new firms plays a crucial role in today's knowledge-based economies. Because new firms are often dependent on external providers of capital that finance the commercialization of a technology, there is a separation between ownership (principal) and control (agent), causing information asymmetries between the two parties (Gompers and Lerner 2004; Kaplan and Stromberg 2001; van Osnabrugge 2000; Gompers 1995; Sahlman 1990; Fama and Jensen 1983). Providers of financial resources therefore bear significant uncertainty and agency risks, which are especially pronounced in the early stages of technology commercialization projects (Baum and Silverman 2004; Mason and Harrison 2004; Gompers 1995).

Traditional players financing early-stage technology-based ventures such as venture capitalists and business angels have developed specific approaches to managing these agency risks. Extant research describes how pre-investment screening of business proposals, contracting solutions and post-investment activities decrease risk and add value to portfolio firms, thereby increasing their probability of success and the return for capital providers (Baum and Silverman 2004; Gompers 1995; Sahlman 1990). Nevertheless, perceived riskiness remains high and an equity gap is observable in the pre-seed and seed stages[4] of technology projects where traditional players do not provide sufficient capital (Mason and Harrison 2004; Murray 1999, 1994). Venture capitalists even seem to have moved from early to later and less risky stages in the last decades and increasingly seem to avoid high technology sectors (Ewens et al. 2015).

In order to fill the equity gap, new financing models have emerged (Block et al. 2017), including capital providers active before the incorporation of a new firm, such as pre-seed venture capitalists (Festel et al. 2015) or founding angels (Festel and De Cleyn 2013). Moreover, there was a surge of investment models based on intellectual property (IP) that aim to build new start-ups around patents or patentable inventions (Festel et al. 2015; Lloyd 2015; Gredel

[4] Pre-seed stage can be defined as the phase before the incorporation of the new venture (Festel et al. 2015). Seed stage is the stage just after the incorporation of a new firm and is dedicated to proof of concept work, product development, business plan development and building of a management team (NVCA 2016).

et al. 2012). These recently emerging business models have so far found little attention in the entrepreneurial finance literature (Block et al. 2017). Our study seeks to fill this research gap. Understanding these players and how they can be successful adds to our theoretical knowledge about managing agency risks and adding value in the earliest stages of technology commercialization. This has important practical implications for fund managers and may trigger increased collaboration between funds and technology owners, eventually enhancing innovation.

We conducted a qualitative, inductive study of IP venturing funds, wherein IP venturing funds invest in patents or patentable inventions in exchange for IP rights or shares of a new venture. We collected and analyzed data on six successful IP venturing cases, covering both fund and deal level as units of analysis. IP venturing funds are a new and little-known phenomenon and represent an appropriate context for studying investment behavior in the earliest stages of a new technology-based venture. This is because they are active in the pre-incorporation phase of a venture and therefore in the earliest phase of commercialization, because they explicitly focus on technology. Our primary aim is to explore business models and success factors of IP venturing funds. We mainly draw on the theory of agency risk in entrepreneurial finance in order to embed our findings and to answer the question of how funds' activities decrease agency costs and add value, eventually leading to a higher success probability for portfolio companies and a higher return for the fund (Baum and Silverman 2004; Gompers 1995; Sahlman 1990).

Our results show that IP venturing funds decrease agency costs and add value through business building activities which exceed the support activities known from traditional players. Funds get actively involved in management, recruit a surrogate management team and provide not only commercial but also technical expertise. We also show that there are two groups of IP venturing funds: In an opportunity-driven investment style the funds act as founder, triggering both opportunity recognition and exploitation. Agency costs are decreased, as principal (fund) and agent (entrepreneur) are the same entity. In a technology-driven investment style, funds focus on technology transfer from research institutions and use novel contracting solutions in order to decrease agency costs and to minimize search and due diligence costs.

These findings contribute to our knowledge about new investment models in entrepreneurial finance by establishing them as players supporting the pre-incorporation phase of new ventures. We further add to our understanding of how high agency risks can be managed in order to increase returns as we provide extensive evidence for novel contracting solutions as well as post-investment approaches such as the use of surrogate CEOs. Our results also highlight the importance of social capital for decreasing agency costs (Eckhardt and Shane 2010; Shane and Cable 2002). In the broader view, we add to extant research on the entrepreneurial process as we show that funds can take over the core entrepreneurial task of opportunity recognition (Shane 2000; Venkataraman 1997; Kirzner 1973). We further provide evidence of entrepreneurship as an eclectically sourced stock of resources (Murray 1996; Gartner et al. 1994).

The paper is organized as follows. We first provide an overview of traditional and emerging players financing new technology-based firms and review extant literature on the existence and management of agency costs in this context. We briefly present previous insights on opportunity recognition as a crucial part of the entrepreneurial process. We follow the current practice of qualitative studies (e.g., Souitaris et al. 2012; Pratt 2008) as we introduce prior findings which inform our inductive study. Subsequently, we describe methods used focusing on the general research design, sample, data and data analysis. We present and discuss our results, followed by a summary of theoretical and practical implications of our findings. We conclude with an overview of limitations of our study and an outlook on further research topics.

2.2. Theoretical background and literature overview

2.2.1. Overview of traditional and emerging business models in entrepreneurial finance

Entrepreneurship is an important way to transfer invention to innovation (Braunerhjelm and Svensson 2010; Audretsch 2007). However, new firms often lack the financial resources to exploit their entrepreneurial opportunities (Mason and Harrison 2004). Providers of financial capital in the early stages of a venture such as venture capitalists and business angels are therefore critical (Festel et al. 2015).

Venture capital firms are formal investors (Festel et al. 2015; Kaplan and Stromberg 2001) which provide capital across different and well-defined stages of the life-cycle of a new firm (Sahlman 1990). Looking at the US market as an example, venture capital funds invested $59.1B in 2015 in over 4,000 deals. More than 1,400 firms received venture capital for the first time (NVCA). Although these numbers are impressive, traditional venture capital is not suitable to satisfy the need for initial funding before and directly after incorporation of technology-based ventures (Festel et al. 2015) and "cannot provide a complete solution to the financing needs of new technology companies" (Hall 2008, p. 27). First, of the total amount invested only 2% (~$1B) was dedicated to the seed stage in 2015, i.e., the stage just after incorporation of a new firm, which is dedicated to proof of concept work, product development, business plan development and building of a management team (NVCA). This share is down from >10% in the mid 1990s which illustrates the shift of venture capital towards later stages (NVCA). Venture capital investors prefer companies that have already decreased technology risk to the point where a product is available and optimally tested with first customers (Festel et al. 2015; Auerswald and Branscomb 2003). This development is also illustrated by the growing average venture capital fund size which more than doubled over the period 1995-2015 to $135M per fund (NVCA) and by the fact that larger funds rather invest in larger companies and later funding rounds (Wright et al. 2006; Murray 1999). Second, funds have become reluctant to finance high technology firms, which require long-term and costly technology development with uncertain outcomes, and increasingly move capital towards less complex technologies (Ewens et al. 2015; Mason and Harrison 2004). Ewens et al. (2015) note that venture capital has moved "from complex technologies where initial experiments cost more towards those where information on future prospects is revealed quickly and cheaply" (Ewens et al. 2015, p. 1).

Investment activity of business angels is less transparent. This informal source of capital for early-stage firms is nevertheless important as they represent the largest source of risk capital and are estimated to provide at least twice the investment amount of formal venture capital (Festel et al. 2015; Bygrave and Quill 2007; Sahlman 1990). Angel investors complement venture capital in terms of financing stages and size as they usually focus their investment on

the seed and early stages of a firm and provide smaller investment tranches of less than ~$150K (Festel and De Cleyn 2013; Mason and Harrison 2004). Like formal venture capital, however, they invest in existing companies (Festel et al. 2015; Smith et al. 2010; Mason and Harrison 2002) as opposed to technology development projects before and at incorporation. This is attributed to the high search costs for individual investors in earlier stages and lack of access to researchers (Harrison and Mason 1992). Business angels are private individuals, who usually invest in what they understand and have a background in (Mason and Harrison 2004; van Osnabrugge 2000). Therefore, only some of them have the required experience and knowledge to be involved in high technology areas (Mason and Harrison 2004).

As a result of the investment behavior of these traditional players, an equity gap remains in the earliest stages of technology development (Auerswald and Branscomb 2003), which can be described as the pre-seed and seed stage. The financial crisis in 2008/2009, the increased pace of technological discoveries and regulatory changes additionally increased difficulties for entrepreneurs in raising funds in these stages (Block et al. 2017). This gap has encouraged financial innovations and the emergence of various players, some of which have found little attention in literature so far (Block et al. 2017; Ewens et al. 2015). These players have heterogeneous goals and use new investment approaches, methods and business models in order to cope with the challenges of investing in new technology-based ventures (Block et al. 2017). Especially "investment models before the foundation of a start-up are fairly unknown" (Festel et al. 2015, p. 372). One example of so-called pre-incorporation approaches is founding angels, i.e., individuals which act as co-founders of scientists and – like business angels – invest their own money (Festel and De Cleyn 2013). These individuals not only provide important funding in the pre-seed stage, but also expertise in technology commercialization. They invest small amounts (in the range of $10-60K) but own a substantial share of the company due to their role as co-founders – usually 10-50% of the start-up at foundation (Festel et al. 2015). Moreover, Festel et al. (2015) have investigated pre-seed venture capitalists, which focus on technology transfer and "finance early stage research at universities or research institutions in exchange for intellectual property (IP) rights" (Festel et al. 2015, p. 381). They consequently

assign the IP to the new venture, build a management team and provide funding and support to the startup (Festel et al. 2015).

The term "IP venturing funds" emerges from our prior research in the field of patent-based investment funds. It describes funds that acquire or gain control over patents or patentable inventions, invest privately or publicly raised funds and try to generate a return for their investors by commercializing the technology through the creation of a new start-up (Gredel et al. 2012). This definition includes but is not limited to the pre-seed venture capitalist funds that support universities' technology transfer offices and invest in university spin-offs described by Festel et al. (2015). The business model of IP venturing funds is based on the notion that many potentially valuable inventions are lying idle (Giuri et al. 2007; Palomeras 2003) because of impediments in the invention-to-innovation process (Guerrero and Urbano 2014; Block et al. 2013; Acs and Sanders 2012; Carlsson et al. 2009; Auerswald and Branscomb 2003). By contributing to the exploitation of such existing technological discoveries and closing the financing gap in the pre-seed and seed stages of commercialization they can create a clear value add for the economy (Baty and Sommer 2002). Although total investment volume might still be small compared to that of venture capital or business angels, IP venturing funds present an interesting approach to studying the specifics of early-stage investments (Block et al. 2017).

2.2.2. Existence and management of agency costs

Information asymmetries and agency costs

Because most entrepreneurs that wish to exploit an entrepreneurial opportunity rely on resource owners such as the ones described above to provide financial resources (Eckhardt and Shane 2010; Sahlman 1990), there is a separation of ownership (principal) and control (agent) which leads to information asymmetries and agency problems (e.g., Kaplan and Stromberg 2001; van Osnabrugge 2000; Sahlman 1990; Fama and Jensen 1983). Resulting agency costs can be attributed to contracting and monitoring costs as well as to "the value of output lost

because the costs of full enforcement of contracts exceed the benefits" (Fama and Jensen 1983, p. 304).

Significant information asymmetries exist before and after the investment decision is made because the entrepreneur possesses private information with regard to the opportunity and with regard to new information emerging from running the firm (van Osnabrugge 2000; Sahlman 1990). This causes high uncertainty and makes the assessment of an opportunity from outside difficult and costly. Second, these information asymmetries lead to two particular agency problems: adverse selection and moral hazard. Adverse selection means that abilities of the agent cannot be fully verified by the principal. "The agent may falsely claim to have certain skills when he or she is hired" (van Osnabrugge 2000, p. 94). Moral hazard refers to behavior which is against the principal's interest. This might include strategies with high personal return for the entrepreneur (e.g., scientific recognition) but low monetary return for the investor, such as the continuation of projects in the case of negative information (van Osnabrugge 2000; Fama and Jensen 1983). It may also cause the agent to take on excessive risk (Gompers 1995; Jensen and Meckling 1976). Even if information is the same for both parties, they are likely to disagree on the right strategies (Sahlman 1990) as "entrepreneurs' private benefits from certain investments or strategies may not be perfectly correlated with shareholders' monetary return" (Gompers 1995, p. 1462). This can cause the agent to withhold information, again increasing information asymmetries. Information asymmetries make monitoring difficult and costly (Fama and Jensen 1983).

The described agency costs are especially pronounced for investments in early-stage and technology-based ventures. Ventures and projects in an early development stage are characterized by a "liability of newness" (Baum and Silverman 2004, p. 415) which refers to the lack of experience and history which could be evaluated to decrease asymmetric information (Hannan and Freeman 1984; Stinchcombe 1965). Besides, they often lack alliances and other forms of social ties (Baum and Silverman 2004). This increases information asymmetries and uncertainty. "This uncertainty is compounded for firms established to pursue commercial applications of new technologies" (Baum and Silverman 2004, p. 415), i.e., R&D intensive firms with high market risk. Gompers (1995) shows that information asymmetries "increase

as assets become less tangible, growth options increase, and asset specificity rises" (p. 1461). Therefore, investors have to deal with greater difficulties and costs for collecting information in a due diligence as technology, product and market are new and adverse selection risk is particularly high (Mason and Harrison 2004). All these factors augment agency costs and the perceived riskiness of new technology-based ventures (Mason and Harrison 2004; Lockett et al. 2002; Murray and Marriott 1998). They also explain why investing in seed capital is considered "a hard way to make money" (Baty and Sommer 2002, p. 290) and why we consequently face a financing gap in the early stages of technology-based ventures (Murray 1999).

The same risks hold true for investments in IP and impede efficient markets for technology (Pries and Guild 2007; Shane 2003). By definition, IP is unique and covers new inventions. Uncertainty is therefore generally high (Braunerhjelm and Svensson 2010; Hall 2008; Svensson 2007). The earlier the development stage of the technology, the higher the uncertainty (Svensson 2007) – not only because of the newness of the technology but also with regard to the readiness of the technology for application in a product and the existence of markets (Pries and Guild 2007). Information asymmetries arise because "an inventor frequently has better information about the likelihood of success and the nature of the contemplated innovation project than potential investors" (Hall 2008, p. 413). Besides, inventors often fear imitation and refrain from full disclosure of their findings, thus keeping their information advantage purposely high (Hall 2008). This is especially relevant for companies that want to avoid knowledge leaks to competitors (Hall 2008; Anton and Yao 1998; Bhattacharya and Ritter 1983). In addition, moral hazard problems are amplified because the goals of an (academic) inventor are often different from the financial goals of an investor (Franklin et al. 2001). These issues make it both difficult and costly to conduct due diligence and valuation (Hall 2008; Pries and Guild 2007; Svensson 2007). Therefore, the "marketplace for financing the development of innovative ideas looks like the ‘lemons’ market" (Hall 2008, p. 413). Research on how agency risks are managed is limited to traditional players such as venture capital or business angels. Newly emerging players in the context of patent-based investments have not been explored even though agency costs are particularly pronounced.

Management of agency costs

According to extant research on managing agency costs in early-stage financing, investors can actively decrease information asymmetries through several interrelated measures: pre-investment screening, contracting and post-investment activism (Kaplan and Stromberg 2001).

Pre-investment screening is based on classical agency theory and aims to reduce information asymmetries "ex ante" (van Osnabrugge 2000). The focus lies on screening business proposals and on gathering information during a due diligence in order to make an improved investment decision (Baum and Silverman 2004; Sahlman 1990). Baum and Silverman (2004) refer to this approach as "acting as a 'scout' able to identify future potential" (Baum and Silverman 2004, p. 411) and aiming at "picking winners" (Baum and Silverman 2004, p. 411). In the context of early-stage investments, where information gathering is difficult, the selection using certain signals and firm characteristics such as patents or top management characteristics plays an important role (Cao and Hsu 2010; Haeussler et al. 2009; Baum and Silverman 2004; Shepherd and Zacharakis 2001; Feeney et al. 1999).

Based on the information gathered during screening, contracts are formulated which decrease identified risks, facilitate monitoring and set incentives for the entrepreneur (Kaplan and Stromberg 2001). They can refer to performance goals or to the behavior of the entrepreneur (van Osnabrugge 2000). Three typical control mechanisms through contracting are known: the use of convertible securities, syndication and staging of capital (Gompers 1995; Sahlman 1990). Convertible securities' main function is to set incentives in such a way that the risk of moral hazard is mitigated (Cornelli and Yosha 2003; Schmidt 2003) and that the entrepreneur puts in an efficient amount of effort (Denis 2004; Schmidt 2003; Cornelli and Yosha 2003). Syndication allows venture capitalists to diversify risks by investing in more firms and to limit the risk of investing in a deal with bad prospects by getting additional evaluations of the opportunity (Gompers and Lerner 2004; Gompers and Lerner 2001). By staging the capital provided to the venture, the investor has the option to discontinue funding when negative information is revealed and success probability is low (Cornelli and Yosha 2003; Gompers

1995; Sahlman 1990). Between funding rounds, the investor re-evaluates the venture and collects new information. The duration and size of funding rounds as well as the frequency and intensity of monitoring depend on the "nature of the firm's assets" (Gompers 1995, p. 1487). The higher the information asymmetries are the more important and valuable frequent monitoring is (Gompers 1995). By holding the entrepreneur on a "tight leash" (Gompers 1995, p. 1462), staging reduces losses from bad decisions and therefore decreases agency costs (Sahlman 1990). Moreover, the entrepreneur is incentivized to maximize value and to meet agreed goals (Cornelli and Yosha 2003).

Post-investment activism complements screening and contracting, assuming that contracts are incomplete and that monitoring is necessary to observe whether the outcomes are as specified in contracts (Bottazzi et al. 2008; van Osnabrugge 2000). By exerting control and being actively involved during the investment, the investor acts "as a 'coach' that can help realize [future potential]" (Baum and Silverman 2004, p. 411) and aims to "build winners" (Baum and Silverman 2004, p. 428). Costly support activities provided by venture capitalists include mentoring, adding and changing managerial resources, strategic advice or support in setting up governance and in getting access to further funding (Bottazzi et al. 2008; Sahlman 1990; Timmons and Bygrave 1986). Investors are furthermore often active on the board of directors (Sahlman 1990). These activities decrease agency risks (van Osnabrugge 2000; Sahlman 1990) and increase the competitive advantage of a firm (Hellmann and Puri 2002). This leads to higher success for these firms: "investor activism is shown to be positively related to the success of portfolio companies" (Bottazzi et al. 2008, p. 488); it also leads to a higher financial return for the investor (Cochrane 2005).

Gorman and Sahlman (1989) show that on average, venture capitalists monitor nine portfolio companies and sit on the board of five of them. They spend ~110 hours per year in direct contact with each of the latter companies (i.e., where they have a board seat) (Gorman and Sahlman 1989). Business angels were found to exert even more emphasis on post-investment activities than venture capitalists (van Osnabrugge 2000). Nevertheless, they do not get involved in day-to-day management (Gorman and Sahlman 1989). Festel et al. (2015) even state that "BAs as well as traditional VCs, normally do not have sufficient time to identify and familiar-

ize themselves appropriately with a potential start-up project and to build a solid relationship with the founders" (Festel et al. 2015, p. 375). It should also be kept in mind that traditional venture capital was found to move towards later stages of firms where information asymmetries are lower. Accordingly, Ewens et al. (2015) found that there is "a significant shift away from value-added 'governance' in the early stages of ventures to more passive `learning' about startup potential" (Ewens et al. 2015, p. 3).

Shane and Cable (2002) argue that economic explanations are incomplete in explaining how information asymmetries and associated agency costs can be managed. Based on organizational theory they state that social ties can mitigate agency risks and are therefore used by venture capitalists to select projects. "[S]ocial ties link the provision of resources to social obligation and social norms of fairness and trustworthiness" (Eckhardt and Shane 2010, p. 64). This facilitates the collection of information, thereby decreasing information asymmetry, and deters the agent from exploiting information advantages (Eckhardt and Shane 2010; Venkataraman 1997; Aldrich and Zimmer 1986). Apart from this solution, information asymmetries and associated agency costs can be fully eliminated through self-financing as stated by Eckhardt and Shane (2010). This means that entrepreneurs must invest their own capital in order to exploit an opportunity (Eckhardt and Shane 2010; Knight 1921).

The management of agency costs has primarily been investigated for the large groups of institutional investors, both business angels and venture capitalists. Understanding how other intermediaries approach this issue therefore might reveal interesting and so far neglected information (Kaplan and Stromberg 2001). New approaches might therefore also have important implications for traditional players active in early-stage financing. IP venturing funds as a new phenomenon represent an appropriate context for studying how agency costs can be decreased because they face particularly high agency costs: first, they are active at a very early stage, even before the venture is incorporated. Second, they have a pure technology focus as they aim to commercialize patents and patentable inventions.

2.2.3. Opportunity recognition

The questions of where opportunities come from and how individuals recognize them are central to entrepreneurship research (Eckhardt and Shane 2010; Kirzner 1997; Venkataraman 1997). Our study did not intend to test existing theory on the nexus of an entrepreneurial opportunity and an individual. Rather, the locus of opportunity recognition became an emergent topic when analyzing our data and extant research therefore informs our results (e.g., Souitaris et al. 2012; Pratt 2008).

Assuming that opportunities exist whether or not they are identified (Eckhardt and Shane 2010; Baron and Ensley 2006), opportunity recognition is the starting point for the entrepreneurial process:

> "The entrepreneurial process begins with the perception of opportunities, or situations in which resources can be combined at a potential profit. Alert individuals, called entrepreneurs, discover these opportunities, and develop ideas for how to pursue them, including the development of a product or service that will be provided to customers." (Shane 2003, p. 10)

The fact that only some individuals will identify a specific opportunity at a specific point in time (Kirzner 1973; Hayek 1945) is attributed to differences in knowledge and information as well as to cognitive differences that allow the individual to make better use of information (Eckhardt and Shane 2010; Lockett et al. 2003; Shane 2003; Shane 2000; Venkataraman 1997).

Access to information. One source of entrepreneurship stems from differences in information about opportunities (Shane 2000; Kirzner 1997). In fact, the same information asymmetries leading to the recognition of opportunities will later make the investment by external parties more risky (Shane 2000; Kirzner 1997). Information asymmetries exist due to incomplete markets, limits of the ability of prices to reveal all information and limits to codify knowledge (Eckhardt and Shane 2010; Akerlof 1970; Hayek 1945). Additionally, people specialize in knowledge, which contributes to an uneven distribution of information with regard to tech-

nologies and markets. Knowledge corridors, search and social ties have been identified as mechanisms explaining different access to information in extant literature.

Knowledge corridors are specific paths through which individuals can obtain idiosyncratic knowledge, i.e., "individual's own circumstances including occupation, on-the-job routines, social relationships, and daily life" (Venkataraman 1997, p. 122). They enable individuals to know about, e.g., new technologies or unused resources, which then leads to the recognition of an opportunity (Eckhardt and Shane 2010). Second, an active and inexpensive search leads to more information and therefore an increased probability of discovering an opportunity (Eckhardt and Shane 2010; Stigler 1961). The individual's experience and knowledge thereby influence how costly the search for opportunities is. Third, information is acquired through social relationships and networks (Burt 1992; Granovetter 1973). Quantity, quality and speed of information dispersion are influenced by relationships and facilitate opportunity recognition (Eckhardt and Shane 2010).

Cognitive abilities. Access to information is not sufficient to identify an opportunity: "recognizing opportunities from information about changes also involves determining the meaning of that information" (Eckhardt and Shane 2010, p. 60). Cognitive abilities contribute to the explanation of why some individuals are able to interpret information and derive an underlying opportunity while others do not, despite having the same information. These abilities are shaped by prior knowledge, i.e., education and employment, the intellectual domain and general life experiences (Venkataraman 1997). Eckhardt and Shane (2010) state that "prior knowledge about such things as markets, technologies, production processes, industries, and customers influences the ability of people to comprehend or interpret new information as it relates to other information" (p. 61). Moreover, individuals differ with respect to their cognitive processes and ability to, e.g., be aware of cross-linkages, evaluate information or challenge assumptions (Gaglio and Katz 2001; Kirzner 1973). Similarly, some individuals are more likely to see opportunities rather than risks when receiving new information (Sarasvathy et al. 1998) or are more creative in using it (Shackle 1982). Empirical findings on these theories, however, are scarce. Shane (2000) shows that different people recognize different opportunities, as one technology can potentially generate more than one entrepreneurial opportuni-

ty. Even for patents, which are public and where access is comparably easy, "only some subset of the population will possess prior information that will trigger the discovery of a particular entrepreneurial opportunity" (Shane 2000, p. 452). The importance of relevant experience and education of the entrepreneur is stressed.

Opportunity recognition in technology transfer. In the literature on technology transfer, opportunity recognition and the decision to commercialize a technology are considered as one of the key issues of spin-offs out of public research institutions (Lockett et al. 2005). Evidence on who identifies opportunities in the context of university spin-offs shows that the inventor and technology transfer offices (TTOs) play the biggest role in recognizing an entrepreneurial opportunity (Lockett et al. 2005; Lockett et al. 2003). Especially in universities which spin off many new start-ups based on university technologies, opportunities are often recognized by TTOs, which support the academics in framing and marketing opportunities (Lockett et al. 2003). Inventors and TTOs are significantly more likely to see an opportunity than people from outside the university, as external actors face high asymmetric information and a lack of access to technologies and associated opportunities (Lockett et al. 2003; Robbie and Wright 1996). Nevertheless, Lockett et al. (2005) and Lockett et al. (2003) find that external entrepreneurs – so called "surrogate entrepreneurs" (e.g., Kassicieh 2011; Franklin et al. 2001) – can be involved in searching for and identifying opportunities. They are even considered to be better at opportunity recognition than academic actors (Franklin et al. 2001) and especially important where "expertise is lacking in the commercial offices of universities" (Lockett et al. 2003, p. 188). Similarly but to a lesser extent, external private sector organizations might play a role in the opportunity identification process (Lockett et al. 2003). Apart from the special context of university spin-offs, there is little extant research on the locus of opportunity recognition in the entrepreneurial process. To our knowledge, this is the first study connecting the literature on early-stage financing business models and research on the identification of opportunities.

2.3. Methods

2.3.1. General context and sample

This study is motivated by the fact that IP venturing funds are an important yet under-researched phenomenon, as their practices and characteristics are little understood. In this context, an exploratory, qualitative research design is well suited to answer our research questions (Eisenhardt 1989). More specifically, we apply a multiple case study design, which is "the preferred strategy when 'how' or 'why' questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real life context" (Yin 2003, p. 1). In addition, the population of IP venturing funds is relatively small, very heterogeneous and opaque. Identifying the entire population and acquiring a large enough share to generate a statistically reliable random sample at this point in time does not seem feasible (Birley et al. 1995; Patton 1990). This inability is even more pronounced because of the privacy of data in the context of IP venturing funds, which is very similar to equity investors in the venture capital or private equity industries (Souitaris et al. 2012; Mason and Harrison 2004). This is to our knowledge the first study to provide insight into IP venturing funds through primary in-depth data, which makes our qualitative analysis particularly valuable.

We applied a multi-case, embedded case study design, where case selection was guided by theoretical considerations (Glaser and Strauss 1967). This corresponds with the goal of case study research to theorize through analytical generalization rather than statistical generalization (Yin 2003). Thus cases are treated as a series of independent experiments and a replication logic is applied (Yin 2003; Eisenhardt 1989). Each case can "confirm emergent relationships" or "provide an opportunity to refine and extend the theory" (Eisenhardt 1989, p. 542). As ours is an embedded case study, our unit of analysis is not only at the fund level but also at the deal level (Yin 2003). Therefore, we identified one specific commercialization project per fund in consultation with the funds.

In a purposeful sampling approach we selected information-rich cases (Patton 1990) along three common parameters: First, the funds' investment approach is to commercialize IP through the creation of start-ups around this IP, therefore they are the primary investors of a venturing project before or at foundation. Based on this condition, a short list of 16 IP venturing funds was collected through desk research as well as interviews with experts in the field. Second, the commercialization project selected out of prior or existing portfolio companies of the fund needs to be successful. The condition of success is important because it characterizes extreme cases from which we can draw insights regarding common parameters influencing the success (Pratt et al. 2006; Eisenhardt 1989): "extreme cases facilitate theory building, as the issues being examined tend to be more visible than in other contexts" (Souitaris et al. 2012, p. 480). The main criteria for a successful project are: (1) The IP venturing fund has invested a material sum of >$500K (Murray 1996); (2) At least a Series A financing round[5] was raised, indicating that the venture has achieved early important milestones in the commercialization process. It did not seem reasonable to impose stronger conditions on the definition of success, such as a completed exit and realized return above a certain threshold (Murray 1996), because the funds in the sample are comparably young and holding periods in IP venturing can be very long. The third parameter for case selection is that principal informants were available and we were able to gain access to them in order to conduct interviews. As in other studies in the field of private investment funds, this condition turned out to be an important limitation to the final size of the sample (Murray 1996). Based on all three criteria, we were ultimately able to select six case studies out of the 16 funds originally identified (37.5%). This number lies in the range of 4-10 case studies which is proposed by Eisenhardt (1989).

The cases cover IP venturing funds active in the US and UK. These countries correspond with the location of the large majority of identified IP venturing funds. Considering the deal level of our cases, we cover a wide range of different technologies which are applied in a wide

[5] Series A financing round is described by NVCA as the first financing event where traditional providers of early stage finance such as business angels or venture capitalists become involved; the company at this point has demonstrated a viable business concept and has completed proof of concept work, financed through pre-seed and seed capital.

range of industries, ranging from biotech and medtech to cleantech. Moreover, cases differ with regard to their development stage. This variance increases the external validity of our study and also characterizes samples in prior studies dealing with technology commercialization, which argue that such an approach creates an in-depth understanding of the new ventures' general development (Politis et al. 2012; Vohora et al. 2004). A summary of further sample characteristics is shown in Table 7. Moreover, a short summary of the rich case descriptions which were compiled in the course of data collection is provided in the appendix.

2.3.2. Data

Data collection took place between April 2016 and December 2016. In order to triangulate data, multiple data sources were used: "the triangulation made possible by multiple data collection methods provides stronger substantiation of constructs and hypotheses" (Eisenhardt 1989, p. 538). As a consequence, internal validity and credibility of the research is increased and the probability of retrospective bias is reduced (Santos and Eisenhardt 2009; Yin 2003). An overview of data sources per case is given in Table 8.

The primary data source is interviews with principle informants of each case. We were able to conduct at least one interview with a principle informant at the fund level. All of the fund managers interviewed have a very high position within the fund (e.g., CEO, investment partner or Vice President of the fund) and were closely involved in the respective IP venturing project. Whenever possible (i.e., where available), this was supplemented by an interview with the CEO of the start-up and/or by an interview with an external informant who was knowledgeable about the particular fund or project. Using multiple respondents both reflects the embedded nature of our case study approach and increases the ability to triangulate data (e.g., Murray 1996; Pettigrew 1973). In total, 11 interviews were conducted, recorded and transcribed. Given the small size of the funds' management teams and start-ups' leadership teams, this is a reasonable number of informants (Souitaris et al. 2012). Each interview lasted between 30 and 100 minutes and all interviews were conducted via phone by the same interviewer. Interviews were semi-structured and questions posed were open, leaving flexibility

Table 7: Sample characteristics

Case characteristics	Case A	Case B	Case C	Case D	Case E	Case F
A. Fund information						
Location	Philadelphia, USA	London, UK	Manchester, UK	Columbus, Ohio, US	New York, US	Boston, US
Year of establishment	2004	2001	2008	2005 (Restarted in 2013)	1999	2007
Fund size	>$1.2B invested since 2004	Invests from balance sheet (£76M in 2015), ~ £85M across three funds	£32M	~$60M across 7 funds ($1M-$22M per fund)	$50M	~$20-40M invested per year
Fund term	Pledge fund structure (no fixed term)	Evergreen model[1], funds with 10 year term	10 years	10-12 years	12 years	Evergreen model, three year rolling investment term
Team size	5	63	5	28	3	3 (~20 engineers internally)
Technology focus	Pharmaceuticals, Biotech	Healthcare, Technology, Cleantech, Biotech	Materials, Med-Tech, Electronics	Advanced Technology, IT, Life science	n.a.	Industrials, Consumer, Financial services, Energy
Regional focus	US	UK	UK	Central Ohio, US	US and Europe	US
B. Investment characteristics						
Inventor	Large company, small biotech company	Professor at associated university	Professor at associated university	Research team at associated university	Research group at research institute	Small tech company
Technology	Anti-interleukin-5 monoclonal antibody	Novel water-saving washing systems using polymer beads	Oxygen-enhanced MRI	Efficient and more affordable natural gas compressor	Fuel cell technology	High voltage ion propulsion technology
Industry/ target market	Treatment of eosinophilic asthma and esophagitis	Laundry industry	Pharmaceutical industry and medical diagnostics	Transportation and oil and gas industry	Electrical components and equipment	Private engineers and research labs
Date of first investment	2004	2006	2008	2013	1999	2008
Status	Exited (trade sale in 2010)	Portfolio company (IPO in 2014)	Portfolio company	Portfolio company	Exited (IPO in 2005)	Portfolio company

1) Money is raised by the funds without a fixed tenure life

for case-dependent inquiries and leading to a smooth course of questions and answers typical for case study research (Yin 2003). A set of guiding questions was used to structure the interviews and addressed the following topics: (1) introduction to the fund's business model and investment strategy, (2) background and starting point of the IP venturing project, and (3) structuring and development of the new venture. This allowed us to explore the creation, structuring and development of IP-based ventures, as well as the contribution and role of the IP venturing fund.

Interviews were complemented by archival data consisting of internal sources in the form of written communication and external sources. External sources covered a wide range of publicly available data such as media clippings, reports, homepages, employee profiles and databases. In addition, a press review was conducted for each fund and IP venturing project. In all over 600 pages of archival data were screened and included in the analysis. These documents were used to triangulate and to complement interview data. In addition, email communication was used to clarify specific questions and to validate case facts and summaries.

2.3.3. Data analysis

We note that this study follows an inductive approach. We did not intend to test theory on early-stage financing or opportunity recognition. Rather, we collected data on IP venturing projects and analyzed it in an iterative way (Corbin and Strauss 2008; Miles and Huberman 1994). First, we conducted a within-case analysis in order to cope with the large volume of data and to get a deep understanding of each individual case and its context (Eisenhardt 1989). We condensed case information, using standardized summary descriptions and tabular displays (Miles and Huberman 1994). Case summaries were validated by the interviewees. This approach to data documentation increases the reliability as well as external validity of the study (Yin 2003). We then started with open coding of the material and assigned data segments to emerging provisional categories (e.g., "investment approach", "IP stage", "identification of opportunity") using the software MAXQDA. Applying the constant comparative method (Silverman 2006), we revisited the data to see which themes fit well to the data from all cases and adjusted categories accordingly. Subsequently, we consolidated categories and

Table 8: Data sources

Data sources	Case A	Case B	Case C	Case D	Case E	Case F
Principal informant 1	**A1**[1]	**B1**	**C1**	**D1**	**E1**	**F1**
Position	Senior Managing Partner, Founder	CEO	Investment Partner (3A)	Senior Director of Venture Capital	CEO, Founder	CEO, Founder
Role	Investor side	Investor side	Investor side	Investor side	Investor side	Investor side
Place/ date of interview	Phone/ 13.09.2016	Phone/ 19.09.2016	Phone/ 04.10.2016	Phone/ 26.10.2016	Phone/ 22.11.2016	Phone/ 25.11.2016
Length of interview	61 min	67 min	59 min	50 min	43 min	46 min
Principal informant 2	**A2**	**B2**	**C2**	**D2**		
Position	CEO Europe of a different IP fund	CEO of venture	CEO of venture	CEO of venture		
Role	External observer	Surrogate entrepreneur	Inventor, entrepreneur	Surrogate entrepreneur		
Place/ date of interview	Phone/ 06.04.2016	Phone/ 04.10.2016	Phone/ 24.11.2016	Phone/ 17.11.2016		
Length of interview	97 min	32 min	30 min	38 min		
Principal informant 3				**D3**		
Position				Executive Vice President		
Role				Investor side		
Place/ date of interview				Phone/ 17.11.2016		
Length of interview				37 min		
Archival data						
Internal sources	E-mail correspondence	E-mail correspondence	E-mail correspondence	E-mail correspondence	E-mail correspondence	E-mail correspondence
External sources	**AP**[2]	**BP**	**CP**	**DP**	**EP**	**FP**
	Media clipping, employee profiles, 10-K form of buyer, press releases, homepages of fund and venture, other external sources (207 pages)	Annual report 2015 of fund, annual report 2015 of venture, press releases, homepages of fund, university and venture, other external sources (222 pages)	Public investor/fund presentations, employee profiles, press releases, homepages of fund, university and venture, other external sources (56 pages)	Media clipping, employee profiles, homepages of fund, university and venture, other external sources (33 pages)	Industry reports, investor reports, fact sheets, employee profiles, homepages of fund and venture, other external sources (82 pages)	Employee profiles, homepages of fund and venture, other external sources (14 pages)

1) The letter-number codes are used in the remainder of the text to refer to specific interview partners 2) The letter code combined with P is used in the remainder of the text to refer to public sources

started to identify appropriate literature for framing our data and to compare initial findings with theory. Thereby we moved from open to axial coding (Souitaris et al. 2012; Strauss and Corbin 1998) and used, for example, constructs from theory on the individual opportunity nexus to code data segments on opportunity recognition (e.g., "access to information").

Second, we conducted intensive cross-case analysis and compared emerging constructs across cases. Our goal was to refine and sharpen emerging "themes, concepts, and possibly even relationships between variables" (Eisenhardt 1989, p. 541) by constantly comparing data, emerging concepts and propositions as well as theory (Silverman 2006). In doing so we recognized a number of similarities and dissimilarities between cases. With respect to the similarities we refined the identified categories and linked them to existing theory. With respect to dissimilarities we identified a pattern between cases and realized that diverging dimensions of some constructs are related to specific dimensions of other constructs. This led us to the conclusion that a dichotomy exists and that our cases can be divided into two groups. As a result of iterations between data, emerging theory and extant research as well as intensive discussions, we developed propositions with regard to constructs influencing the return of IP venturing projects for funds in different contexts (Eisenhardt 1989). These propositions lay the basis for further research in this field and can be tested in future quantitative studies.

In presenting our results from qualitative data we follow prior studies (e.g., Souitaris et al. 2012): where appropriate we make use of "power quotes" in the text in order to illustrate our findings and to support arguments through primary data in a vivid way (Pratt 2009, 2008). These quotes are complemented by "proof quotes" presented in case-ordered tables which contain additional evidence for the arguments made in the text.

2.4. Results and discussion

We begin with a presentation of success factors common to all IP venturing funds in our sample. We subsequently show that investment styles of IP venturing funds can be differentiated into two groups. We then present our findings with regard to investment-style specific success factors.

2.4.1. Common characteristics: IP venturing funds as business builders

IP venturing funds are active business builders. All six cases analyzed provide extensive evidence that fund managers get involved in the recruitment of a surrogate management team, take over interim management positions and provide extensive operational and technical support. These activities add value to their portfolio and decrease agency costs. The added value therefore exceeds the sheer provision of financial capital; IP venturing funds refer to themselves as "venture development organizations" or "business builders" as opposed to pure financial investors. Table 9 presents our data on these three themes for all six cases.

Recruitment of surrogate management team. IP venturing funds create a start-up in order to commercialize patents or patentable inventions. Their activities therefore start before the incorporation of the venture when there is no existing management team (Festel et al. 2015). This is illustrated by the following quote by the fund manager of Case E:

> "We have to create a business leadership team, whereas in a traditional venture model you have an entrepreneur or founder that tends to be more a business entrepreneur […] So I think that was the largest challenge we had." (E1)

As shown in Table 9, an external CEO and complementing management team were recruited by the IP venturing fund in all cases studied for this paper. We use the term "surrogate management team" following the existing concept of "surrogate entrepreneurs" which has so far only been researched in the context of university spin-offs. These entrepreneurs are defined as individuals external to the university who take on the role of the entrepreneur with or without involvement of the inventor (Festel et al. 2015; Kassicieh 2011). Our findings extend this concept and show that surrogate management teams are not only important for commercialization of university IP but also when the IP source is corporate, such as in Case A.

The recruitment of a surrogate management team is considered a key task and at the same time a major challenge of IP venturing: "Something that you have to become very good at is recruitment" (C1). The fact that recruitment is a core competence of an IP venturing fund is exemplified by Case B which maintains its own executive search function. Here, the fund's

services even go beyond recruiting as it maintains a business unit specializing in executive development that provides extensive mentoring and coaching for the surrogate CEOs. In areas which are not renowned centers of entrepreneurial and venture capital activity, the recruiting task is considered especially difficult, as illustrated by the following quote from the fund manager in Case C:

> "We get [external managers] from wherever we can. It is probably the biggest challenge because we're based in Manchester. So Manchester is about 200 miles away from London. And in the UK everything happens in London. So the biggest challenge that we have is getting talented people to come and work in Manchester." (C1)

Whereas an external CEO is recruited after incorporation in all six cases, the role and degree of involvement of the inventor varies. In Cases A and B he was not involved at all, but was involved as Chief Scientific Officer/Chief Technology Officer or as member of the technology advisory board in all other cases. From Case C we not only learn how critical recruiting is for the venture but we can also infer that the fund maintains the right to replace the CEO – a measure known from venture capital (Sahlman 1990). Moreover, the academic might grow into the commercial role and in fact be the CEO at a later point:

> "Unfortunately, it didn't work out with the CEO that we got in. [...] and I was the only person really who had the experience in the technology and at least some business experience, having been in the company for a while then, to salvage the situation." (C2)

Recruiting a surrogate management team affects the success of a venture in two ways. First, the management can be purposefully selected according to the specific needs of the venture and the development stage of the technology; it can also be set up so as to optimally complement the skills of inventors (if available and involved in the venture). CEOs in the cases studied have relevant industry and commercialization experience which proved extremely important (Kassicieh 2011; Franklin et al. 2001). In addition, external entrepreneurs are characterized by a higher financial motivation (Franklin et al. 2001) and a different mindset than academic entrepreneurs "that makes them better equipped to deal with opportunities and ob-

stacles related to financing and developing" technology-based start-ups (Politis et al. 2012, p. 175).

These features can complement traits associated with the original inventors of new technologies, who often lack commercial experience (Braunerhjelm and Svensson 2010; Franklin et al. 2001) and – driven by scientific rather than financial goals – are highly committed to and focus on the development of the technology (Franklin et al. 2001). Having a commercially-oriented surrogate CEO in the driver's seat of a new venture corresponds to the Schumpeterian view that different skills are required for invention and commercialization. The combination of skills and human resources might give the start-up a competitive advantage (Kassicieh 2011). The fund manager of Case B describes this task of connecting the two worlds:

> "You are backing people; you're just doing it in a two-stage process, whereas the conventional view of the world is you back management, management, management. We would concur with you back people, people, people. […] you have to do it in a two stage process and you have to have the skills to bring those two worlds (academics and management) together. That's the core idea." (B1)

Moreover, the fund can focus on the quality of the technology when deciding on a project to finance. The quality of management teams plays an important role in the due diligence of venture capitalists, which was even found to be overstated: "VCs also appear to make a common attribution error overemphasizing startups' human capital when making their investment decisions" (Baum and Silverman 2004, p. 411). Unlike this approach, IP venturing funds source technology and management independently and can therefore optimize both, as described by the founder and manager of the fund in Case F:

> "[T]eams and good CTOs [...], the technology execution teams, actually, can be a commodity if you have a good way of managing for that kind of talent. […] so then the only thing that really mattered was for us to secure interesting intellectual property." (F1)

Table 9: IP venturing funds as business builders

Case	Recruitment of surrogate management team	Interim management positions	Operational support
Case A:	**Recruitment considered key task.** • "We only acquired the asset, and we didn't acquire anyone from [the IP source]." (A1) • "There are […] auxiliary industries […]. So you don't need the inventor anymore." (A1) **Relevant experience of CEO.** • "The experience of [the] management team […] was essential." (AP) **Social capital (network).** • "All the senior executives come from people who have either worked with us or worked for us in the past." (A1) • "We had a good rolodex of highly skilled individuals who knew this molecule." (A1)	**Fund manager as interim CEO.** • "He [fund manager] […] served as its Chief Executive Officer and President from January 2004 to December 2005." (AP) **Role in board of directors.** • "He [fund manager] […] served as its Chairman from January 2004 to January 2007." (AP)	**Business-related activities.** • "We did more research on various conditions that were driven by high levels of eosinophils." (A1) • "We went out to larger, much larger venture capital firms, and we said, […] this is a good opportunity, we need more money." (A1) **Expertise.** • "We have operational experience ourselves, in the pharmaceutical industry. So we know that space." (A1)
Case B:	**Recruitment considered key task.** • "The management team, […] were all hired by our Executive Search business." (B1) • "The purpose of that business unit is to help our management teams be the best they can be." (B1) **Relevant experience of CEO.** • "I had demonstrated some small company capability […] in the clean technology area." (B2) **Social capital (long-term relation, network).** • "We would rehire him for one of our spin-offs." (B1) • "The bigger we get, the bigger our network gets. […] They quite often leverage personal networks in order to shore together a shortlist." (B1)	**Fund managers/employees as interim management.** • "We never were big enough to have a CFO for some time in the business. So actually we had the support of [the fund]'s financial manager." (B2) • "Many of our employees do [take executive roles in these ventures]. [...] They'll then find the one project that they are the most passionate about and [...] they'll go and join that company […] sometimes as Chief Executive but more commonly as Chief Technology Officer or Chief Business Officer. " (B1) **Role in board of directors.** • "They always have – and I always welcome this – a director on the board, so every month you have direct contact with a [fund] director." (B2)	**Business-related activities.** • "It's a major feature, not just in the early stage but even in the growth stage. [The fund has] capability and people who are dedicated to assisting the company." (B2) • "You get financial support, you get legal support, you get HR support, […] in a very hands-on fashion and this is crucial." (B2) • "We have a capital markets team, whose job is to […] build relationships with investors." (B1) **Technology-related activities.** • "We had to send one of our own chemists in to go and work out what it is that was happening at the molecular level." (B1) **Expertise.** • "The skills are a lot more hands-on, business building skills, than traditional venture financial investment type skills." (B1)

Note: The letter-number and letter-P codes refer to specific interview partners and public sources as indicated in Table 8.

Table 9: (continued)

Case	Recruitment of surrogate management team	Interim management positions	Operational support
Case C:	**Recruitment considered key task.** • "We started to help build up a management team. […] because in a university spin-off you don't have a management team. " (C1) • "We hired an external CEO to come into the company to run it. And in many ways, that's the preferable way of doing it. Unfortunately, it didn't work out with the CEO." (C2) **Social capital (network).** • "We're obviously quite well networked. […] We have partners in London […], Scotland, […] America [...] our networks and our knowledge of talent is quite broad." (C1)	**Fund managers/employees as interim management.** • "Sometimes we do take an interim executive position. So if there is a particular need for finance director and they can't find one, then we might step in on an interim basis and do that." (C1) • "We've never taken an interim executive position in [the venture]." (C1) **Role in board of directors.** • "They've always had a presence on our board, and that input has been helpful at various times." (C2)	**Business-related activities.** • "They have provided support when we've needed it. In non-financial terms, they have provided advice and good contacts, networks. It's been very helpful." (C2) • "They've also been helpful in identifying other potential funds to work with" (C2) • "The intensity of how you do that obviously is much more intense in the early days." (C1) **Expertise.** • "[…] decades of relevant hands-on experience in all aspects of growth-phase technology businesses. […] both on the operational side and on the investment side." (CP)
Case D:	**Recruitment considered key task.** • "We're identifying the business leads or individuals who will become the CEOs of those companies and literally build them from the ground up." (D3) • "[The inventors] didn't have any business experience." (D2) **Relevant experience of CEO.** • "They're people who have had some pretty significant technology, management, executive, entrepreneurial experiences." (D1) **Social capital (long-term relation, network).** • "[The CEO] had previously been involved with [the fund] when he was chief financial officer at [another venture]" (DP) • "I just do a lot of breakfasts and lunches and a lot of networking, just meeting as many people as possible." (D1)	**Role in board of directors.** • "And by sitting on the board we're very aware of what it is they're looking for." (D1)	**Business-related activities.** • "They have a whole host of resources for the entrepreneur. It's a one-stop shop. They understand all the issues a startup goes through." (D2) • "[…] helping them understand how to raise money, from whom to raise money and how to craft a business model and a business plan […] increase the likelihood that they'll be successful and attractive to an acquirer." (D3) • "[The fund …] also helped us connect with our first customer. They also helped us with PR, […] different things that a small business doesn't have the resources for." (D2) **Expertise.** • "[The fund manager] has probably forgotten more about early-stage start-ups than a lot of people will ever know. He's just a valuable resource" (D2)

Note: The letter-number and letter-P codes refer to specific interview partners and public sources as indicated in Table 8.

Table 9: (continued)

Case	Recruitment of surrogate management team	Interim management positions	Operational support
Case E:	**Recruitment considered key task.** • "We had to find somebody that agreed to join the company and help navigate the company through all the challenges of growing the business. So I think that was the largest challenge we had." (E1) **Relevant experience of CEO.** • "We would recruit key commercial people." (E1) **Social capital (network).** • "I use networks, picking up the phone and calling people I trust in that sector, who can then make referrals. So this is something that's very important." (E1) • "In Silicon Valley there's also a whole network of serial entrepreneurs that have experience in running start-ups. So you plug into those networks to find the right candidate." (E1)	**No formal interim management position.** • "In the interim, though, my fund would provide a lot of the start-up support services." (E1)	**Business-related activities.** • "Spin out the IP into a start-up in which we would guarantee funding and guarantee to write the business plan and provide support services to make sure the start-up succeeds." (E1) • "This model lends itself to providing a business incubation or accelerator support to do a lot of these shared services that a company needs in formation, because there's a million things to do. […] if you're doing several of these a year, they all need the same help." (E1) **Expertise.** • "The problem is that a lot of these people are patent attorneys or patent specialists, and doing IP venturing is a completely different set of skills that they don't have." (E1)
Case F:	**Recruitment considered key task.** • "Our internship program is designed to provide each investment company in our portfolio with unique resources to top talent from the nation's leading universities." (F1) • "The strategy […] was that actually teams and good chief technology officers and technology investors, the technology execution teams, can be a commodity if you have a good way of managing for that kind of talent." (F1) **Social capital (network).** • "I always stayed very close to networks like Caltech, Princeton, MIT." (F1)	**Fund managers/employees as interim management.** • "He [the CEO] was from inside the team." (F1) • "We have a roster of fantastic technology officers and fantastic talent that can build technology so quickly and we had about 20 people on payroll at the end of the day." (F1) • "If everything in this company we're about to build up and fund, if everything doesn't work and is just broken, the last resort is I'll step in for a short period of time and I can be the CTO. But I never had to do that, because we always had a roster of fantastic CTOs." (F1)	**Business-related activities.** • "[The fund] invests resources and capital, […] provides access to a platform of computational and proprietary data sets." (FP) **Technology-related activities.** • "For building a couple of physical prototypes we did that with [external partner] and it was otherwise entirely resourced from inside my team, from engineers that work with me." (F1) **Expertise.** • "We bring together a team of leading in-house mathematicians, programmers and technology development managers who work closely with each investment to ensure commercial growth." (F1)

Note: The letter-number and letter-P codes refer to specific interview partners and public sources as indicated in Table 8.

Second, drawing on the theory of social capital (Eckhardt and Shane 2010; Venkataraman 1997; Aldrich and Zimmer 1986) we suggest that surrogate CEOs and other managers recruited by IP venturing funds are less prone to agency problems than entrepreneurs in a model where they independently found a venture and seek early-stage finance for it. Surrogate CEOs often specialize in the early commercialization phase of technologies and once they have successfully managed this stage for a start-up they frequently move on to the next opportunity. They therefore might be hired again for future management positions if they prove loyal to the fund managers: "We would rehire him for one of our spin-offs" (B1). Moreover, surrogate management is most often recruited from the network of fund managers: "All the senior executives come from people who have either worked with us or worked for us in the past" (A1). Such social ties have several effects that decrease agency risk and information asymmetries. Social ties allow information to be gathered quickly and in a cost-efficient manner which reduces information asymmetries (Eckhardt and Shane 2010; Aldrich and Zimmer 1986). Additionally, social obligation and trust lower the risk that information asymmetries are exploited (Eckhardt and Shane 2010; Gulati 1995). Finally, there is some empirical evidence that the use of surrogate entrepreneurs leads to a more successful commercialization than when the inventor is the commercializer (Kassicieh 2011; Braunerhjelm and Svensson 2010; Chrisman et al. 1995).

Interim management positions. In addition to recruiting surrogate management teams, IP venturing funds also leverage their internal resources and take interim management positions in the newly created ventures. This can reach the extreme that the CEO is recruited from inside the fund, such as in Case F, and remains in this position. More often, however, the funds provide interim management in the very early stage of the start-up when there is no management. For example, in Case A, the fund manager acted as president, CEO and Chairman in the first year after founding of the company and remained Chairman afterwards. In Cases B, C and E, the fund took over the management of the new company in what was referred to as a "transfer period during formation of the start-up" (E1), i.e., the period of 1-2 years after the first investment of the fund until a suitable surrogate CEO is found. In Case B, the investment manager additionally took over the CFO role in the early stage of the company. Being in a

management position during this period implies that the fund managers are fully in charge of the founding activities and setup of the new venture (Cases A, B, C, E, F). In addition to management functions, the funds usually take board seats in the new ventures (Cases A, B, C, D). This is in line with the role of traditional venture capitalists in their portfolio companies (Gorman and Sahlman 1989).

We propose that this active managerial involvement can also have a positive impact on the success of the venture. First, managers of IP venturing funds are extremely experienced in IP commercialization. New ventures might therefore benefit from their professionalism and experience both in the short and long term. Standard activities in the formation of the venture, such as establishing governance and reporting structure, or writing business plans need to be done for every venture and can become routine: "If you're doing several of these a year, they all need the same help" (E1). A more structured and sophisticated way of setting everything up can be expected from this routine than is likely when an entrepreneur is doing this for the first time. This, in turn, can provide the venture with a competitive advantage. Second, agency costs in this phase are decreased even more than in the case of surrogate entrepreneurs. Principal and agent are both from the IP venturing fund and therefore the information asymmetry with regard to management behavior and the risk of moral hazard is mostly eliminated. This allows for better decision making when it comes to more substantial rounds of financing (Festel et al. 2015). This is well expressed by the fund manager of Case F:

> "If [somebody inside the fund] stay[s] involved in the company then my investment in that company is closer and guaranteed success because they stay in the network. And that eliminates one of the biggest challenges with venture capital funds, which is this question of governance and control" (F1).

Operational support after incorporation. The operational involvement of IP venturing goes beyond the foundation phase. Whether or not fund managers take over a formal management position, they are involved in commercial activities in the early commercialization phase, e.g., conducting market studies as well as giving support in marketing and public relations activities. They also leverage their network to find customers for the new venture. Moreover, they

provide basic support and administrative services. In Case B, the fund even maintains a business unit dedicated to providing "administrative and company secretarial support" (BP) to its portfolio companies. IP venturing funds also support their portfolio companies with regard to financial and legal questions and help them in later funding rounds to raise money – e.g., by coaching or by opening up their network. Some funds even have technical resources and scientific staff within their team and provide extensive support, e.g., for developing the prototype. This is illustrated by the following quote from Case B:

> "We were not meeting industry standards for lipstick and curry powder and no one knew why. In fact, we had to send one of our own chemists in to go and work out what it is that was actually happening at the molecular level, which we eventually did. We eventually solved that problem." (B1)

Overall, the operational support includes the whole range of services needed in the early stages of a start-up and collaboration between the fund and the venture is extremely close, which is illustrated by the following quotes:

> "They have a whole host of resources for the entrepreneur. It's a one-stop shop. They understand all the issues a startup goes through." (D2)

> "In the early stage [we talked] almost on a daily basis." (B1)

This extensive support is only possible with the deep relevant expertise of fund managers and – in some cases – relatively large teams. For example, the fund manager in Case A has worked as a senior executive in a large pharmaceutical company and therefore has relevant operational experience in the industry. Also, it was often stressed in the interviews that business-building, entrepreneurial skills are required to provide this kind of operational support.

> "The skills are a lot more hands-on, business building skills, than they are traditional venture financial investment type skills." (B1)

In order to support the ventures technically, some of the funds maintain larger teams of technicians and scientists. The fund in Case F, for example, employs ~20 engineers who play an important role in the development of prototypes.

We propose that these early activities – like the provision of interim management – are compensated and may result in a higher return (Cochrane 2005) due to the value added by a professional setup and the advice in many business and technology related aspects (Metrick and Yasuda 2010; Hellmann and Puri 2002; Sahlman 1990) as well as decreased agency costs. The extent and intensity of support services goes beyond the model known from traditional venture capital. Gorman and Sahlman (1989) find that lead venture capitalists spend ~110 hours per year with a portfolio company, which is clearly exceeded by all IP venturing funds in our sample. In fact, activities rather resemble the behavior of business angels, which focus on exerting control "through active involvement in the investment" (van Osnabrugge 2000, p. 97) and "hands-on guidance and assistance" (van Osnabrugge 2000, p. 106) in order to decrease agency costs. The provision of administrative shared services and technical support corresponds more to services supplied by incubators (Bøllingtoft and Ulhøi 2005). We confirm the conjecture of Festel et al. (2015) that IP venturing funds can therefore familiarize themselves better with the company and collect "deeper and more complete information on the company" (Festel et al. 2015, p. 377), which decreases information asymmetries and has high value for making well-informed financing decisions in later stages (Festel et al. 2015; Gompers 1995). The resulting competitive advantage due to improved operations and the decreased agency risks may lead to greater success of the venture and a better return for the fund (Cochrane 2005; Sahlman 1990).

Summarizing the success factors which emerged from our data with regard to business-building activities, we can make the following propositions:

Proposition 1A: Active business-building activities of IP venturing funds provide the venture with a competitive advantage and decrease agency costs, which leads to a higher financial return.

Proposition 1B: Active business-building activities are moderated by relevant industry experience and commercialization expertise within funds.

2.4.2. Differences between IP venturing investment styles

Conducting cross-case comparisons, we recognized that despite the apparent similarities of IP venturing funds as active business builders, investment styles of IP venturing funds can be clustered into two groups. We propose that a dichotomy exists and present insights from our cases describing the respective investment styles. Subsequently, we investigate the distinct strategies of the funds in each group to manage the risks associated with IP venturing.

2.4.2.1. Technology-driven versus opportunity-driven investment styles

Investment styles of IP venturing funds can be differentiated by three characteristics: purpose, approach to deal origination and the corresponding origin and stage of IP. In Table 10 we present our data on the dimensions of these characteristics in all six cases. The first group – consisting of Cases A, E and F – can be described as applying an "opportunity-driven" investment approach. The approach of Cases B, C and D can be called "technology-driven".

Purpose. The purpose of the funds' investment activities refers to the broader goals and strategy as explicitly stated by the fund managers or in public accounts. Although all of the funds analyzed in our case studies aim to generate a financial return, it emerges from the data that central parts of the description of the funds' goals and strategy differ, demonstrating a different self-perception. One group of IP venturing funds focuses on identifying promising IP assets that might be undervalued and where the fund sees a clear path to increase the asset value. The following quote illustrates this purpose for Case A:

> "[…] the focus is on the maximization of the intellectual property value in a non-litigation setting." (A1)

The purpose of Cases B, C and D differs from this first group. Their purpose is a focused commercialization of technologies stemming from scientific research and their strategy is

tailored to technology transfer with the additional goal of generating new sustainable ventures and creating positive economic impact:

> "The single line that we use to describe [the fund] is evolving great ideas into world changing businesses." (B1)

In Case D the fund manager even states that apart from the financial return the explicit purpose of the fund is "to influence the creation of successful companies that will create new wealth and anchor that wealth in this region" (D3).

Approach to deal origination. The approach to deal origination describes the logic by which the funds identify assets for investment according to the previously described strategy. For the first group of funds, the approach to originating interesting IP is based on an industry and market perspective. For example, in Case E the fund is constantly analyzing markets and evolving technologies that might disrupt the market in the future. It then looks for corresponding technologies that can solve a potential need and subsequently identifies patents that protect these technologies:

> "[Our approach is] market-driven. So we look at these inflexion points, we identify core technologies to achieve those new market goals, like new product or service ideas, and then who in the world is developing very interesting IP in these areas. And then I get on a plane and go see these people and confirm that they are world-class and that they are willing and interested in even doing a spin-off." (E1)

In Cases A and F, the approach is also based on an industry- and market perspective, yet more event-driven. The fund managers observe the market and react to windows of opportunity, in which the value of IP is not recognized by their original owner. This is expressed by the fund manager in Case A:

> "We are constantly looking at the market, constantly looking for opportunity for arbitrage." (A1)

Table 10: Technology-driven versus opportunity-driven investment styles

Case and investment style	Purpose	Approach for deal origination	Origin and stage of IP
Case A: opportunity-driven	**Focus on IP value maximization.** • "[…] the focus is on the maximization of the intellectual property value in a non-litigation setting." (A1)	**Identifying IP opportunities.** • "[Most funds …] spend a fair amount of time reviewing business proposals, evaluating them and deciding which ones they want to pursue further […]. We do not operate like that." (A1) • "[W]e look at the industry in its entirety, and we identify opportunities, where there are dislocations or opportunity for arbitrage. When we identify those, we then go and acquire assets to build companies to play in the dislocation that we have seen." (A1) • "We are constantly looking at the market, constantly looking for opportunity for arbitrage." (A1)	**Opportunity-dependent search for IP from different sources.** • "We are constantly looking at opportunities across the board, we are constantly in the deal flow, in other words we are close to academic institutions, we are close to pharmaceutical companies, large pharmaceutical companies, small pharmaceutical companies." (A1) **Patented technology.** • I acquired […] the product. […] the actual biological agent itself, […] the intellectual property around it, […] the regulatory package around it, all the clinical trial results, the filings with the regulatory authorities [...]." (A1)
Case B: technology-driven	**Focus on technology transfer.** • "We'll invest very early, right at the very beginning. We call it the Eureka moment. [...] The single line that we use to describe [the fund] is evolving great ideas into world changing businesses." (B1) • "All these companies focus on high technology, university-associated spin-offs." (BP)	**Screening university inventions.** • "We have a scientific team go through these disclosures, who'll decide that it's worthwhile spending time on it; that there is something in the waterless washing machine." (B1) • "We see those disclosures and the first part of the process is you try and decide what to do with all of these disclosures, whether to spend some time on them, whether to spend a bit of money." (B1)	**Link to several universities.** • "The [fund] was set up to invest in university spin-offs, initially in the UK but in the last five years we've expanded to the United States. The business model is to enter into long term partnerships with leading research-based universities." (B1) **Patentable invention.** • "You get this disclosure, this Eureka moment. That's the start and that's the raw material." (B1)
Case C: technology-driven	**Focus on technology transfer.** • "It's a seed fund. So it's an early-stage fund, and it's intended to invest in a first investor in a university spin-off." (C1) • "Since 2008 the team have built and refined a 'gold standard' model for University Technology Commercialization Funding." (CP)	**Screening university inventions.** • "On average, the University [...] has around 250 invention records - as it calls Eureka concepts - that go through the initial stages of the business evaluation process every year. […] a decision on whether to license [...] or to spin the technology off [...] is taken. It's at this stage that [the fund] enter[s] the frame." (CP)	**Link to one university.** • "[The fund's] remit was to invest in spin-offs from the University of Manchester. So it had a single-university focus, which was Manchester." (C1) **Patent filed.** • "At the point where [the inventor] presented it, it was more or less a theoretical study." (C1)

Note: The letter-number and letter-P codes refer to specific interview partners and public sources as indicated in Table 8.

Table 10: (continued)

Case and investment style	Purpose	Approach for deal origination	Origin and stage of IP
Case D: technology-driven	**Focus on technology transfer.** • "We have a dual purpose, one is to influence the creation of successful companies that will create new wealth and anchor that wealth in this region, but then we also measure our success on the return of investment from those companies." (D3)	**Screening university inventions.** • "In a typical year we get 500-600 enquiries and 300-350 of those are what we call qualified [...]. From that we meet with roughly 200 entrepreneurs [...], and then we will run 125-150 of those through a product market customer validation process; what we really want to understand is: is there a customer, is there someone willing to buy that product?" (D3)	**Link to several research institutions in the region.** • "[The university] represents a third of the opportunities that we look at, the other major institution is a research hospital." (D3) **Patentable invention.** • "All the inventor had was CAD drawings, so they had modeled what the system would look like." (D3)
Case E: opportunity-driven	**Focus on IP value maximization.** • "The idea was to take very exceptional IP and create spin-offs from it. [...] It was world-class IP, but not just IP." (E1) • "This is pre-seed level-type projects, where you have good IP and you have maybe an early-stage prototype or proof of concept. So it really was early-stage venture capital." (E1)	**Actively searching for opportunities.** • "There are some very important inflexion points, and coming up with those strategic market goals first and then working backwards into the technology, then backwards into the IP is how we did it. So we try to be much more market-driven than the traditional science-push model of universities." (E1) • "[Our approach is] market-driven. We look at these inflexion points, we identify core technologies to achieve those new market goals, […] and then who in the world is developing very interesting IP in these areas." (E1)	**Opportunity-dependent search for IP from different sources.** • "[The IP] was primarily [from universities and research institutions]." (E1) • "I only invest if we own the IP, and I know a lot of universities, especially in USA, which because of [...] restrictions cannot assign the IP over into a new company. They have to exclusively license." (E1) **Patented technology.** • "You have good IP and you have maybe an early-stage prototype or proof of concept." (E1)
Case F: opportunity-driven	**Focus on IP value maximization.** • "The only thing that really mattered then was for us to secure interesting intellectual property and then wrap a company around it." (F1) • "[The fund] is a venture fund and it was at one time an incubator and is now more so an early-stage venture fund." (F1)	**Identifying IP opportunities.** • "[A popular consumer product was] banned and taken off the streets. […] all of a sudden ion-generating fans just became absolutely vilified and nobody wanted to touch these things. Nobody wanted to invest in it. [...] And all of a sudden they don't have a market. [...] We found a couple [of patented technologies] that were interesting and we picked out one." (F1)	**Opportunity-dependent search for IP from different sources.** • "I always look for patents that were not filed in association with any university. […] if they filed it chances are it's an expensive patent. So I'm going to have to pay a couple million USD for that." (F1) **Patented technology.** • "There was a proof of concept. [...] [The inventor] had clearly described in the patents that this was a viable thing." (F1)

Note: The letter-number and letter-P codes refer to specific interview partners and public sources as indicated in Table 8.

Instead of identifying promising market opportunities and then looking for the corresponding IP, the second group of IP venturing funds is starting from the inventions made in universities or other research institutions and deal origination is focused on screening disclosures describing these inventions. The fund managers evaluate the technology and try to validate its application and marketability. This is illustrated by the following quote:

> "We would have a scientific team go through these disclosures, who'll decide that it's worthwhile spending time on it; that there is something in the waterless washing machine." (B1)

Origin and stage of IP. The origins of IP commercialized by IP venturing funds are organizations or individuals that own IP and do not necessarily commercialize it themselves. The first group of funds approaches all kinds of different sources in order to find IP. This includes small and large corporations, research institutes or individual inventors. The source is dependent on the market opportunity identified:

> "We are constantly looking at opportunities across the board, we are constantly in the deal flow, in other words we are close to academic institutions, we are close to pharmaceutical companies, large pharmaceutical companies, small pharmaceutical companies." (A1)

Often, universities are not the preferred source of IP for these funds. Prices for IP stemming from renowned research institutions are believed to be high and potentially overvalued which would contradict the fund's investment strategy in Case F. Besides, universities often have restrictions regarding the full transfer of ownership rights to a newly created venture; such restrictions are considered unfavorable by the fund in Case E. The first group of IP venturing funds looks out for patented technologies. In all three cases the patent was not only already filed, but there was at least some proof of concept, in some cases an early prototype, available. In Case A, the drug backed by the IP had already successfully passed Phase 1 of the FDA drug approval process.

Unlike this situation, funds in the second group are focused on university spin-offs and are even specifically linked to one or more research institutions. This is highlighted by the fund manager in Case C:

> "[The fund's] remit was to invest in spin-offs from the University of Manchester. So it had a single-university focus." (C1)

In Cases C and D, the funds were explicitly set up to provide funding for technology commercialization and to fill the funding gap for university spin-offs that prevailed before. This was the same for Case B before it expanded its activities to several universities across the UK. It should be noted that while these funds are geographically and/or contractually closely linked to specific institutions, they are organizationally fully independent from the universities and their technology transfer offices. Because of their link to research institutions, the second group of funds starts the commercialization projects at a very nascent stage of the IP. Most often, the fund's involvement starts when an invention or scientific observation is disclosed to the university, as described by the fund manager in Case B:

> "Often you're investing just based on a simple observation." (B1)

From the findings presented, we conclude that the underlying strategy, sourcing approach, origin and stage of IP are consistent for Cases A, E and F. As their approach is driven by specific opportunities which are picked and exploited by the fund, we refer to the investment style of this group as "opportunity-driven". This is the opposite of Cases B, C and D, which are characterized by a "technology-driven" investment style. This dichotomy relates to and confirms a point made by E1, who – apart from the fund behind Case E – has been involved in both kinds of IP venturing investments.

> "IP venturing […] means different things to different people: if you talk to the university audience, IP venturing means traditional technology transfer, where they would spin off core IP probably with a professor and they would create a start-up; if you go into the corporate world, however, corporate IP venturing means spinning off much

more developed IP, which is very competitive but maybe non-core to the business." (E1)

We are to our knowledge the first to show empirical findings on different investment styles in IP venturing. We thereby contribute to our understanding of the business model and expand prior definitions which are restricted to the aspect of technology transfer (Festel et al. 2015). This dichotomy influences origination and structuring of deals and implies different characteristics of IP commercialization projects. It emerges from the data that style-dependent success factors have to be differentiated. We present these findings in the following.

2.4.2.2. Opportunity-driven investment style: IP venturing funds as entrepreneurs

In the opportunity-driven investment style, the fund acts as founder and entrepreneur. In order to identify opportunities, the funds rely on proprietary access to information through analytics tools and personal contacts and benefit from their industry know-how. Opportunity recognition through the fund is compensated through a high founder equity share and leads to decreased agency costs. Table 11 presents data backing our findings.

Before any commercialization can happen, an entrepreneurial opportunity stemming from a technology or a market need has to be identified (Lockett et al. 2003; Venkataraman 1997). The nexus between an individual and a valuable opportunity is therefore the precondition for entrepreneurial activity and a central premise of entrepreneurship research (Venkataraman 1997). In the traditional entrepreneurship model this individual will then trigger the exploitation of the opportunity and seek to gain support from resource owners (Eckhardt and Shane 2010). Our analysis of IP venturing funds following an opportunity-based investment style shows that fund managers take over the identification of an opportunity and therefore act as entrepreneurs and founders of the new ventures. This is illustrated by the following quotes:

"[The fund manager] co-founded [the venture] in January 2004." (AP)

"Yes, I was the trigger for the start-up." (E1)

Table 11: Opportunity-driven investment style: IP venturing funds as entrepreneurs

Case and investment style	Fund as founder	Repositioning of IP	Access to information	Cognitive abilities
Case A: opportunity-driven	**Fund referred to as founder.** • "He [the fund manager] co-founded [the venture] in January 2004." (AP) • "Two of the founders were […] partners in [the fund], a Philadelphia intellectual-property venture-capital firm." (AP) **High founder share.** • Initial equity split: 100% Fund (acquisition of IP via cash)	**Opportunity recognition.** • "We can see which opportunity exists for us to go and build the company into."(A1) **Repurposing of IP.** • "Large pharmaceutical companies like to tell a drug what it must do for them. I like to ask the drug, what can you do for me […]. If you say the drug is safe and biologically active, and it reduces eosinophils that leads you to the conclusion that maybe eosinophils is not the silver bullet for asthma. So the question is, what other conditions exist." (A1) • "We were able to identify a couple of these conditions. […] So if you add 1 plus 2, you will get 3, which is, there was a good chance that this drug would work in those two conditions. […] we have now done the work to connect the dots." (A1)	**Patent data.** • "We screen new patent applications." (A1) **Industry information.** • "When you run a trial for a particular drug, [...] the scientists involved would like to publish the results of their work. So there is a clear amount of information that you can get on any product that is in development." (A1) • "Both companies […] published the results of their studies, and they explained within the studies, this is what we did, here is the result and the results were not successful." (A1) **Network.** • "When we see an opportunity [...] one of the first questions we ask ourselves is, who do we know in that space, who do we know in that company, who do we know that is active with assets, and who can we best have a meaningful conversation with, to assess the opportunity. So we believe very strongly that relationships matter." (A1)	**Expertise.** • "I have the background in that space, and therefore I have the sensitivity to understand the products in the asthma space."(A1) • "Myself and my two partners have tremendous industry experience, […] we were senior executives in a number of pharmaceutical companies […]. So because we have industry experience, […] we identify opportunities." (A1)

Note: The letter-number and letter-P codes refer to specific interview partners and public sources as indicated in Table 8.

Table 11: (continued)

Case and investment style	Fund as founder	Repositioning of IP	Access to information	Cognitive abilities
Case E: opportunity-driven	**Fund referred to as founder.** • "[The fund] seeds new start-up ventures, securing founder's equity positions in these companies in exchange." (EP) • "Yes [I was the trigger for the start-up]" (E1) **High founder share.** • Initial equity split: 65% Fund, 35% Research institute in exchange for assignment of the IP	**Repurposing of IP.** • "Because [the institute] had a lot of military government projects looking at fuel cells, it was a leader [in fuel cells]. So I reached out to them and said: why don't we take this core IP and create a dedicated company focused on applying fuel cells into mobile appliances." (E1) • "I went to them, and they hadn't even thought about doing it, because they were just doing military projects on fuel cells." (E1)	**Patent data and analytics.** • "I also used analytics to look at inflexion points in the market, so we knew that fuel cells were going to be important in the future." (E1) • "Before we went on the road, talking to people, we did a lot of market, technology, IP analytics." (E1) **Network.** • "It's very important about networks and relationships. […] you have to have somebody that knows the heads of IP […] and find a way of getting into these corporations or research centers." (E1)	**Expertise.** • Prior education and employment of fund managers: extensive IP commercialization experience, extensive experience in mobile phone industry (C-level)
Case F: opportunity-driven	**Fund referred to as founder.** • "The only thing that really mattered then was for us to secure interesting intellectual property and then wrap a company around it." (F1) **High founder share.** • Initial equity split: 90% Fund, 10% Inventor in exchange for licensing the IP • "We originally gave them 10% [equity in exchange for the license]." (F1)	**Opportunity recognition.** • "We saw this thing and we saw the prototype – we thought that's pretty cool." (F1) **Repurposing of IP.** • "It was designed originally to be a fan, a consumer-purchased fan and not a particle accelerator." (F1) • "So we said okay, let's build the best miniature particle accelerator […] and use this guy's technology." (F1)	**Patent data and analytics.** • "We find machine-learning algorithms against manually collected, transcribed multi-language dictionaries of technology terms. […] what you find is that a lot of technologies can be translated internationally, they can also be translated across domains in the sciences." (F1) • "I'd find these technologies that were being published by MIT, I would translate them into other domains or other languages and [...] I would search small companies that basically had the same kind of investments that MIT did." (F1)	**Expertise.** • "I've been a technologist my whole life. I've been an electrical engineer; I've been in tech ever since. I know the tech environment in North America pretty well. […] I know this community like I know my own family." (F1)

Note: The letter-number and letter-P codes refer to specific interview partners and public sources as indicated in Table 8.

In accordance with our description of the opportunity-driven investment style, fund managers observe developments in the market or a certain industry and identify promising technologies and IP assets. They explicitly do not look for business proposals of other entrepreneurs but aim to come up with their own business idea and to use the IP to realize it:

> "Rather than advertise how much money we have, rather than advertising and spending time evaluating other people's proposals, we do the work ourselves, find the opportunity and then we go and create a company." (A1)

When comparing this to the deal genesis of the technology-driven investment style, we recognize that in these cases the initial opportunity recognition is done by the inventor – even if in the very nascent form of an invention disclosure. In Cases B, C and D, the inventors not only found a new technology but were also aware of an application, which is illustrated by the following quote from the inventor in Case C:

> "When I started the process of patenting the work that we were doing, I already knew there was value in terms of what we can offer to the pharmaceutical industry because even as an academic, I was doing a lot of work with the pharmaceutical industry for years. So there was a clear demand. So that was very obvious." (C2)

The opportunity-based approach rests on the notion that IP assets are not fully utilized by their inventor because the inventor has not recognized the potential (Giuri et al. 2007; Palomeras 2003) or because there are alternative opportunities to the one originally exploited (Shane 2000). For example, in Case A the fund became aware that the development of a patented molecule was stopped by a large pharmaceutical company. However, the fund managers recognized ~20 alternative applications for this molecule and at this point in time decided to buy the underlying IP. Eventually, development was started for the two most promising applications. Similarly, the fund managers in Cases E and F identified applications different from those envisaged by the inventor:

> "I went to them, and they hadn't even thought about doing it, because they were just doing military projects on fuel cells." (E1)

> "It was a market for somebody and then it collapsed – and why [should we] build this to the prototype stage? Because I figured I knew I could sell it. I knew that it had a product market." (F1)

Building on extant literature on the individual opportunity nexus, the ability to spot entrepreneurial opportunities stems from knowledge and information differences as well as from cognitive differences between individuals (Eckhardt and Shane 2010; Lockett et al. 2003; Shane 2000; Venkataraman 1997; Hayek 1945). With respect to the former aspect IP venturing funds applying an opportunity-based investment style benefit from public access to patents. Data on patents and patent applications is screened (Case A) and proprietary analytics are used to analyze patent data. This creates an information asymmetry about the content and quality of patents as well as about technological developments in the market (Cases E and F), which are not obvious and not accessible to others:

> "What we tend to do is find machine-learning algorithms against manually collected transcribed multi-language dictionaries of technology terms. […] and what you find when you do this is that a lot of technologies can be translated internationally, they can also be translated across domains in the sciences." (F1)

In addition, the access to industry specific information facilitates the recognition of opportunities. Case A illustrates the role of industry specifics; for example, there is high transparency regarding study results of drug development in the pharmaceutical industry. Access to information also comes from social ties and relationships (Burt, 1992; Granovetter, 1973). IP venturing funds leverage their extensive networks in order to identify opportunities, to get access to specific IP which has been identified and to evaluate whether an opportunity should be exploited. The latter aspect is illustrated by the following quote:

> "When we see an opportunity [...] one of the first questions we ask ourselves is, who do we know in that space, who do we know in that company, who do we know that is active with assets, and who can we best have a meaningful conversation with, to assess the opportunity. So we believe very strongly that relationships matter." (A1)

In addition to access to information, cognitive abilities play an important role in the identification of opportunities. These abilities are shaped by prior experiences in the form of education and employment (Venkataraman 1997). In fact, in all three cases applying the opportunity-based investment style, fund managers have built extensive expertise in the respective area of the opportunity: In Case A, the fund manager had several years of experience in the field of respiratory pharmaceuticals. In Case E, fund managers combine IP commercialization skills and experience in mobile appliances. The manager in Case F is an electrical engineer and deeply connected with the tech community representing the target market for the identified product. These characteristics enable the funds to take over the core entrepreneurial task of opportunity recognition.

Our findings regarding funds as entrepreneurs have several implications. First of all, the structure of the deals is affected. The fund holds founder shares, which can be interpreted as compensation for opportunity recognition. The terms of licensing or assigning the IP are negotiated on a deal by deal basis and the original IP owner is compensated via cash (as in Case A) or via an equity share in the newly formed venture (as in Cases E and F). Case F illustrates that the fund as entrepreneur might benefit from an information advantage as the inventor is not fully aware of the potential of the IP. The problem of adverse selection in high technology markets is turned upside down. As a result, funds following the opportunity-driven investment style hold between 65% and 100% of the equity of the venture at incorporation (excluding stock options for management). This share allows for a very high level of influence and a higher share at exit than a traditional venture capital investor when holding the amount invested constant.

> "[My fund invested] only $2M. But because […] we formed the company, we got much more than just the $2M. We ended up getting 65% at the beginning, and at the point of IPO, we probably had a diluted stake of about 12%, which is great." (E1)

Second, agency costs at the very early stages of the venture are significantly decreased. In the traditional entrepreneurship model an entrepreneur has to rely on resource providers in order to exploit an identified opportunity. The asymmetric information that creates this opportunity

and allows the entrepreneur to identify it then creates problems of moral hazard and adverse selection (Eckhardt and Shane 2010; Shane 2000; Kirzner 1997; Venkataraman 1997). These agency costs are eliminated if entrepreneurs invest their own capital (Eckhardt and Shane 2010; Knight 1921) which is the case for funds acting as founders and entrepreneurs. They therefore actively decrease one of the major risks associated with investing in the early stages of technology commercialization (Mason and Harrison 2004). There is no adverse selection because "the financing decision [is] in the hands of those people who have all the information about the opportunity" (Eckhardt and Shane 2010, p. 63). Moreover, a clear focus on return maximization is given from the beginning. The remaining technology risk is limited, as at least a proof of concept is already available for the technology and due diligence is conducted by the fund. We suggest that the compensation of opportunity recognition and the reduction of agency costs increase the return for the fund and therefore we conclude with the following propositions:

Proposition 2A: Access to information including active search and cognitive abilities shaped by prior experience enable IP venturing funds to recognize an opportunity and find corresponding IP.

Proposition 2B: Opportunity recognition through IP venturing funds is compensated through a high founder share and significantly decreases agency costs, which leads to a higher financial return.

2.4.2.3. Technology-driven investment style: IP venturing funds as contractors

In the technology-driven investment style, IP venturing funds rely on specific contractual measures in the very beginning of technology commercialization in order to decrease agency costs. In addition to business-building activities mentioned before, these measures lay the foundations which allow them to focus on "building winners" instead of "picking winners" and to decrease deal acquisition and due diligence costs. Data on our findings is presented in Table 12.

The group of funds following a technology-driven investment style is focused on technology transfer from research institutions and the financing of university spin-offs. These funds face enormous agency risks which are due to the typical information asymmetries between the inventor who in these cases (Cases B, C and D), unlike in the opportunity-driven investment style, also identified the opportunity. As previously stated, investment starts at an extremely early stage of technologies, which augments risk and uncertainty and makes due diligence difficult and costly (Mason and Harrison 2004; Murray and Marriott 1998). In addition, information asymmetries and the risk that these asymmetries can be exploited are high due to the different mindset at the starting point of the entrepreneurial opportunity (Franklin et al. 2001). This is well described by the fund manager B1:

> "Financiers tend to be around profit maximization whereas academics are more about impact maximization." (B1)

Funds try to manage these agency risks through a mix of enhanced control mechanisms and contracts (van Osnabrugge 2000; Gompers 1995; Sahlman 1990) as expressed by the following quote:

> "Right at the beginning we take on a lot of risk. There's no doubt at all about that. What we tried to do was to change the economics of risk." (B1)

These mechanisms include a contractually fixed option to invest, staged investments including very small amounts in the beginning and methodologies to quickly decrease technological risk as well as a financial structure that circumvents a valuation at the very beginning of the investment.

Option to invest. Venture capital investors are found to secure the option to invest in existing portfolio companies "if the company requires and warrants additional capital" (Sahlman 1990, p. 507). They therefore make use of "rights of first refusal or pre-emptive rights" (Sahlman 1990, p. 507). This approach is in a more extreme way adopted by those IP venturing funds commercializing university inventions. They contractually secure proprietary access to university disclosures or the right to be the first investor in spin-offs from the university which

Table 12: Technology-driven investment style: IP venturing funds as contractors

Case and investment style	Staging	Right to invest	Avoidance of valuation
Case B: technology-driven	**Small PoP[2] investments for validation.** • "The first investment will typically be very small, maybe £100K [... and] is spent trying to fail the technology. It's spent focused on critical pieces of work which if they're not successful can mean that the technology doesn't go forward." (B1) • "Once you've gone through and approved the concept work it follows the more traditional pattern. You do seed/Series A investing." (B1) • "The first thing I would do is ask the academic what would happen if I swallowed these beads [...] The academic hadn't thought through these questions. [...] you try and fail." (B1) **Firepower.** • "[The fund] has very deep pockets that allow them to follow their money in larger and larger amounts as they like the look of how the business is developing." (B2)	**Exclusive partnerships.** • "The business model is to enter into long term partnerships with leading research-based universities. These partnerships are often 10, 15, 20 year partnerships." (B1) • "That's how we got the IP because we had a long-term partnership with the university." (B1) • "[The fund] formed exclusive, 'first rights' deals with universities in order to demonstrate they had sufficient access to guaranteed deal flow sufficient to deploy their capital." (BP)	**Convertible notes.** • "Grub capital[1] tends to go in by way of a debt instrument, what you would refer to as proof of concept capital." (B1) **Pre-set terms for equity distribution.** • "If you decide to do a spin-off, based on any of those disclosures the terms of that spin-off are already pre-determined. It doesn't matter whether it's a piece of software or whether it's a potential cure for cancer or whether it's a clever piece of engineering, everything is valued the same and the terms of the spin-offs are exactly the same right at the beginning. " (B1) • "Before any money's gone into the company that's the equity split: [fund] 30%, university 30%, academic inventors 40%." (B1)
Case C: technology-driven	**Small PoP investments for validation.** • "The model they use when they work with us is to give small funding on a recurrent basis when we really need it." (C2) • "The proof of principle projects were between 15,000-100,000." (C1) • "The objective of proof of principle projects [...] is to do something commercial and to prove the principle of commercial value." (C1) • "Of these 31 projects about seven or eight resulted in a spin-off company." (C1) **Firepower.** • "If you want to make profit, you have to follow your investment." (C1)	**Right of first refusal.** • "We had a right to first refusal to invest in Manchester deals. So that means they could offer deals to others, but we always had the right to match the price. So effectively, we would have first look." (C1) • "So it wasn't a strict exclusivity in that we could just do anything we wanted. So we only had the right to match the price of anybody else." (C1)	**Pre-set terms for equity distribution.** • "In return for PoP investments the [fund] receives a share in the value of the IP." (CP) • "The proof of principle projects were between 15,000-100,000 [...] and in return for that, we would get 15% share in the underlying IP." (C1) • "The beneficial owner is 85% academic, 15% the university. [...] The inventor sold […] 15% for the PoP investment. [...] He gave away a further 15% to the TTO, and in return for that, he got the patent costs, the patent agent filing, and he got effectively a bundle of services." (C1)

Note: The letter-number and letter-P codes refer to specific interview partners and public sources as indicated in Table 8 1) Grub capital = pre-seed capital 2) Proof of principle

Table 12: (continued)

Case and investment style	Staging	Right to invest	Avoidance of valuation
Case D: technology-driven	**Small PoP investments for validation.** • "We usually target somewhere between six and 12 months as a time period to go from the proof of concept to then a next round of financing." (D3) • "We were able to get a little bit of this pre-seed money from them to start looking at it. And based on the results […], [the fund] was encouraged enough that they made an additional number of investments." (D2) • "Our methodology is built around the idea to get a customer first and then build the product, and so we have lots of successful examples of that over our respective careers, so that's what we try to enforce on most of the entrepreneurs, and that includes the raw technologies coming out of the research universities. " (D3) **Firepower.** • "We are a full life cycle investor, so we want to begin as early as it makes sense given the opportunity, and then our strategy is to be an investor and work with the company through the point of exit." (D3)	**High demand in region.** • "The funds that were offered are not a requirement. If the business leader wants to go and get funds somewhere else, great, that's fine with us. The problem is that in the Midwest there weren't a lot of funds that were at this early, early stage and as a result that's why the State of Ohio in conjunction with the university had to basically create these funds because there just wasn't the capital to grow these startups in Central Ohio." (D1) • "They are funded under a state program and Ohio State funds them as well. And basically they're responsible for managing that fund. So that fund goes to companies that are formed specifically around Ohio State University Technology." (D1)	**Convertible notes.** • "The first investment, the pre-seed investment was convertible notes." (D3) • "That [Proof of concept investment], […] is generally in the form of a convertible note because at the same time we can't really value what this actually looks like yet." (D1)

Note: The letter-number and letter-P codes refer to specific interview partners and public sources as indicated in Table 8.

allows for a constantly large and high-quality deal flow. In Case B, the fund has a formal relationship with the university which allows it to see all inventions disclosed to the university by inventors and to invest in them.

> "Under these partnership agreements we get to see all those disclosures and to give you an idea of the numbers involved, a university like Oxford would have about 400 disclosures a year." (B1)

Similarly, the fund in Case C has a "right to first refusal" for all spin-offs of the university. Case D differs in this respect: there is no strict exclusivity to invest in university spin-offs. However, there is a strong link to the university because it is an investor in some of the funds involved in Case D. Therefore, a very strong link and tight collaboration exists without any contractual agreements. Besides, the lack of funding for proof of concept and pre-seed projects in the region, which is described by the fund manager, does not leave many financing alternatives for university spin-offs. This ensures a large and constant deal flow despite the lack of exclusivity rights. The access to a large pool of patentable inventions and patents significantly lowers transaction costs with regard to deal origination which were found to be especially high for early-stage technologies (Harrison and Mason 1992).

Staging. Venture capital funds invest at distinct stages of a company's life (Sahlman 1990). Thereby they "preserve the right to abandon a project whose prospects look dim" (Sahlman 1990, pp. 506–507) and set high incentives for the entrepreneurial team. Our data show that IP venturing funds also make use of this mechanism. In the beginning of an IP commercialization project, they make very small investments aimed at verifying the viability of a technology, and time to the next round is relatively short. This confirms prior findings that – as agency costs increase (e.g., for early-stage projects or a high share of intangible assets) – the duration between financing rounds becomes shorter and the amount of capital smaller (Gompers 1995). In our case studies the first investment – known as Proof of Principle investment – is up to $100K and is used to prove the commercial value of the technology. This stage is expected to last from 6 to 12 months. In Case C, 10% of the funds available are explicitly dedicated to Proof-of-Principle projects:

> "It was effectively a proof of principle project to move the technology on a bit and to get it to the point where you could start taking some images; because at the point where [the inventor] presented it, it was more or less a theoretical study." (C1)

Time between investments is used to gather information and to re-evaluate the prospects of the venture, and funding is discontinued if negative information is learned (Gompers 1995; Sahlman 1990). IP venturing funds have developed specific methodologies for making effective use of the money and time spent. For example, the fund managers in Case D go through a product market customer validation phase even before the incorporation of the venture. In Case B, this methodology is based on a "fail fast" approach:

> "The methodology we developed […] is based on theory of falsification. So what we're trying to do is find a reason to fail things rather than to make them work." (B1)

With this approach, funds try to advance the respective technology as quickly and capital-efficiently as possible. They set the incentives by which involved academic inventors can focus on commercially-oriented development activities. Staging of investment allows them to monitor the progress and keeps the academic from taking advantage of information asymmetries. Moreover, it allows the funds to collect information and decrease information asymmetries and uncertainty with regard to the technology. This significantly improves their decision of whether to abandon the project or to invest in further, much larger financing rounds (Cornelli and Yosha 2003; Gompers 1995; Sahlman 1990).

In order to really benefit from this mechanism, funds need to have a critical size so as to have the financial firepower to follow the money and to avoid dilution. In the three cases examined, the funds participated in all investment rounds conducted so far and invested between $1M and $15M, which corresponds to 15%-50% of the total investment raised by the ventures. The importance of this is expressed by the fund manager in Case C:

> "You have to follow. If you want to make profit, you have to follow your investment and you have to carry on investing." (C1)

The approach of making many small investments in the beginning and accepting that only a few of those will turn out to be promising after a few years shows that technology-based IP venturing funds do not aim at "picking winners" in the first place, but focus on contracting solutions and on "building winners" (Baum and Silverman 2004, p. 413). Thereby they avoid putting much effort and money into due diligence which is characterized by high uncertainty as well as high costs for gathering information. The fund manager of Case B summarizes this investment logic:

> "We thought we could [design an economic model] if we only invested very small amounts of money right at the very beginning and [if] we allowed a Darwinian theory to play out. We get very high failure rates in the first few years; about 50%, 60% of our things fail within three years. But because we've only got a small amount of money on each one, it hasn't proved too catastrophic in terms of the overall returns. What we have done in our first three years is we've gained intimate knowledge of each of these projects. We think that that means that we've had to be less good than average at making bright decisions down the line. It's like knowing your family by the time you get there." (B1)

Financial structure. Other structural features which help IP venturing funds to decrease due diligence costs are the use of convertible notes and pre-set terms for structuring the investment. This allows them to avoid a costly valuation of the IP or the new venture in the very beginning. The first tool to do so is the use of convertible notes instead of equity, which is one of the well-known control mechanisms applied by venture capital funds to manage agency costs (Gompers 1995; Sahlman 1990). The use of convertibles is illustrated by the following quote:

> "[The proof of concept investment ...] is generally in the form of a convertible note because at the same time we can't really value what this actually looks like yet." (D1)

In addition, Cases B and C have pre-set terms to structure the investment. In Case 3, the fund gets a fixed percentage (15%) of the underlying IP in return for the proof of principle investment, which can be between $15K and $100K. This means that the fund receives either 15%

of the royalties if the technology is licensed or 15% of the equity of a newly-founded venture – no matter if the fund continues to invest or not. The cap table at incorporation is therefore standardized: beneficial ownership is shared between the inventor (85%) and the university (15%). The inventor can "sell" 15% to the fund in exchange for the proof of principle investment and another 15% in exchange for patenting and other services provided by the university. This is similar to Case 2, where the structure at incorporation is fully determined by a contract between the fund and the university. In the case we analyzed, "the standard equity split at the beginning is 30% to [the fund], 30% to the university and 40% to the academic inventors" (B1), which compensates the fund for pre-incorporation activities and the university for patenting costs. Moreover, the initial pre-money valuation of the venture at which the fund makes its first investment is pre-determined at £750K.

The described mechanisms circumvent a valuation at the first investment and defer it to the next round of financing. This lowers the cost of due diligence and valuation of the project and again shows that the focus is not on "picking winners" (Baum and Silverman 2004, p. 413). This is different from the behavior of traditional venture capital funds which tend to focus on due diligence and ex-ante screening (van Osnabrugge 2000). The pre-set equity distribution has another advantage: given the same investment of cash or other resources, the fund on average gets a higher equity stake in high-value projects and a lower equity stake in low-value projects.

All of the above-stated mechanisms decrease agency costs. They lower deal acquisition and due diligence costs as well as set incentives for the academic inventor. Deals are originated and structured in a way that allows the fund to concentrate on creating value ex-post. This in turn can lead to a higher return for the funds. We therefore make the following propositions:

Proposition 3A: Contractual control mechanisms applied by IP venturing funds decrease deal origination and agency costs, which leads to a higher financial return.

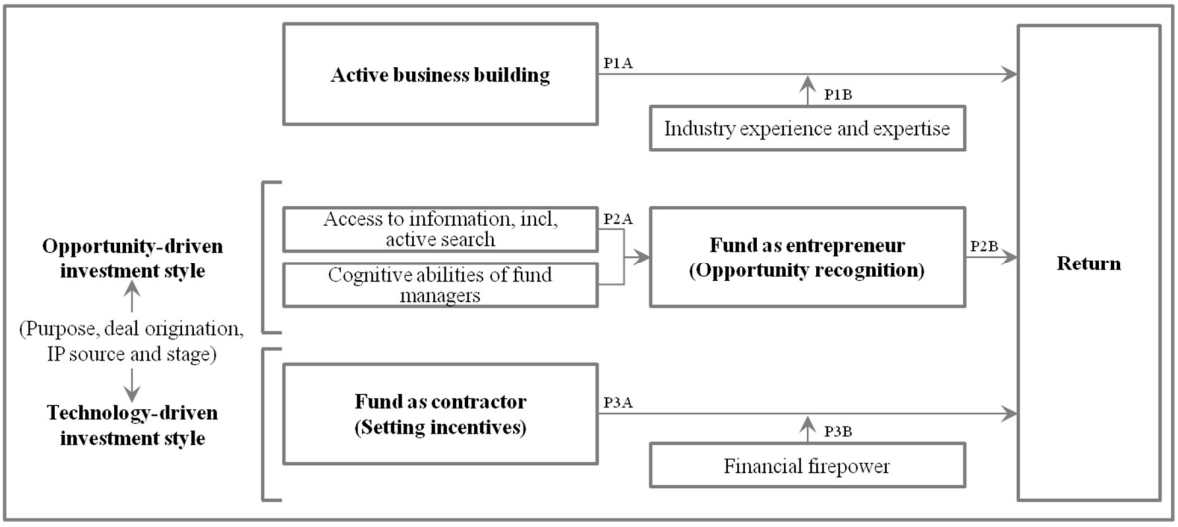
Proposition 3B: The effect of contractual control mechanisms on return is moderated by the ability of the fund to invest in later financing rounds and to avoid dilution.

2.5. Implications and conclusion

The aim of the paper is to investigate the phenomenon of IP venturing which has so far been neglected in the literature. We explore the business models and success factors of IP venturing funds and analyze common characteristics as well as differences between cases. We embed our findings in extant literature and draw on the theory of managing agency risk in entrepreneurial finance to develop six propositions which are depicted in the model in Figure 8.

Figure 8: Overview of six propositions on IP venturing funds

Source: Own illustration



Our results show that IP venturing funds act as business builders, adding significant value and decreasing agency costs through active involvement in management functions, recruitment of a surrogate management team, and extensive business and technical support services. The impact of these activities on the return of the deal is moderated by the industry experience and commercialization expertise of fund managers. Moreover, we establish a dichotomy in investment styles of IP venturing funds. Some funds apply an opportunity-driven investment style in which fund managers take over the task of opportunity recognition and de facto become the entrepreneur. This approach reduces principal agenct conflicts in the early stages of the commercialization project as entrepreneur and financial resource provider are the same entity. Other funds are characterized by a technology-driven investment style. On top of business building activities common to both IP venturing investment styles, they apply some nov-

el contracting approaches aiming at decreasing agency costs and keeping search and due diligence costs low.

Theoretical implications

Players in entrepreneurial finance. Our study contributes to the literature on innovations in entrepreneurial finance. We are the first to investigate IP venturing funds using primary data from interviews with fund managers. It has been stated that new and heterogeneous players have emerged but have been largely neglected in extant research (Block et al. 2017; Ewens et al. 2015; Auerswald and Branscomb 2003). This specifically includes pre-seed funds (Festel et al. 2015) and patent-based investment funds, which generate a return by investing and commercializing patents and patentable inventions through different pathways (Block et al. 2017; Krech et al. 2015; Gredel et al. 2012; Benassi and Di Minin 2009). We shed light on IP venturing as one of these pathways. We show how IP venturing funds create new ventures around given patents or patentable inventions and how they provide funding to these projects before and after incorporation. IP-based investment funds therefore not only provide funds to those entities from which they acquire IP and which can use the proceeds to finance entrepreneurial activities (Block et al. 2017); they are also active in funding new ventures created around the acquired IP. We can therefore put them in the context of pre-seed funds that "finance research in high technology sectors […] in exchange for IP rights" (Festel et al. 2015, p. 389).

Moreover, our cases do not converge to a coherent set of practices; rather, a dichotomy emerges indicating two distinct investment styles applied by IP venturing funds. IP venturing funds are not only focused on an investment style supporting technology transfer (Festel et al. 2015) but also on identifying and exploiting specific opportunities based on existing IP from all possible sources. We add to the entrepreneurial finance literature by expanding the concept of Festel et al. (2015) as pre-seed technology-based investing is not necessarily bound to the context of research institutions and not necessarily driven by a technology push. Our description of the opportunity-based investment style represents a new form of IP investing which has to our knowledge never been investigated. Both approaches are likely to complement tra-

ditional providers of finance in the pre-incorporation phase – especially regarding the move of venture capital in later and less risky stages (Ewens et al. 2015; Auerswald and Branscomb 2003). As they continue to invest in future and larger investment rounds, they then become substitutes for traditional entrepreneurial finance providers.

Management of agency costs. By proposing success factors of IP venturing funds, we also contribute to our knowledge of how early-stage financing models can manage agency costs and add value to early-stage technology projects so as to increase return (e.g., Gompers et al. 2005; Kaplan and Stromberg 2001; van Osnabrugge 2000). We thereby draw on agency theory to discuss the impact of IP venturing funds' activities. Although there is plenty of literature on theoretical arguments and empirical evidence of how venture capitalists and business angels manage agency risks, little is known about how emerging players in the field of entrepreneurial finance approach this issue. We show that IP venturing funds put less focus on pre-investment selection and concentrate on post-investment activities and contracting solutions. We also find evidence for alternative approaches to handling agency risks, including social capital and self-financing (Eckhardt and Shane 2010).

First, our results show that all IP venturing funds put strong emphasis on "building winners" (Baum and Silverman 2004, p. 413) by providing extensive support activities post-investment which are valuable and can increase the return upside for the fund (Hellmann and Puri 2002; Kaplan and Stromberg 2001). The measures are similar to what we know from venture capitalists and business angles: e.g., adding management resources or providing strategic and operative support. However, activities start before the incorporation of the new venture when there is no management team. Funds steer and manage a project until they have recruited a surrogate management team (and sometimes beyond this phase) and they provide technical resources and shared services. Activities therefore go beyond traditional venture capitalist and business angel support and are much more intense at the beginning of the project. This is in line with what has been reported on pre-seed venture capitalists. In addition, we contribute to a deeper understanding of how external CEOs and other members of the management of new start-ups are involved and recruited (Festel et al. 2015; Politis et al. 2012; Kassicieh 2011; Franklin et al. 2001).

Furthermore, our findings with regard to the recruitment of a surrogate management team add to the nascent evidence of the importance of social capital in managing information asymmetries and moral hazard (Eckhardt and Shane 2010; Shane and Cable 2002; Shane and Stuart 2002). We find that social ties exist between fund managers and surrogate CEOs recruited by the funds: they are recruited from the fund manager's network or might be hired again for another venture of the fund. These ties facilitate information gathering (Eckhardt and Shane 2010; Aldrich and Zimmer 1986) and decrease the risk of moral hazard due to social obligation and trust (Eckhardt and Shane 2010; Gulati 1995). In some cases, fund managers become CEOs or members of the top management team of a venture themselves, which increases this effect and significantly decreases agency risks.

Second, we show that the two distinct investment styles apply different approaches to manage risk and uncertainty. Our differentiation of investment styles shows that IP venturing funds focused on technology transfer – in addition to post-investment activities – rely on contracting solutions to decrease agency costs. We find new mechanisms such as the contractual fixed sources for deals or pre-set valuations and cap tables. These mechanisms shift focus further away from the attempt to pick winners and instead enable close monitoring by the fund. They are also appropriate for balancing the differences in behavior and motivation between a commercially and financially driven fund and a scientifically driven academic inventor. Thereby, funds can set incentives for the academic (if involved) to behave in a more commercially-oriented way (i.e., reducing moral hazard) and to drive the de-risking of technology in a structured manner. Investment rounds are shorter and smaller in the pre-seed stages. Funds therefore accept high failure rates in the beginning but keep potential losses low (Kaplan and Stromberg 2001). As staging mechanisms and "fail fast" approaches show, contracting and post-investment support are tightly interrelated (Kaplan and Stromberg 2001). In the opportunity-based investment style, mechanisms are much more similar to contracting mechanisms known from traditional venture capital investing.

IP venturing funds following an opportunity-based investment style keep agency costs low through a completely different approach: entrepreneurial and financing resources stem from the same entity (Eckhardt and Shane 2010); this way the principal agent relationship between

entrepreneur and investor is resolved. We contribute to the entrepreneurial finance literature by showing that funds can in fact take over the core entrepreneurial task of opportunity recognition. The IP market has been referred to as a "lemons" market because of the high information asymmetries in the context of early-stage technologies and because inventors (especially companies) want to keep their inventions secret (Hall 2008; Shane 2003; Anton and Yao 1998; Bhattacharya and Ritter 1983). In the investment model we describe, the fund manager identifies an opportunity and the IP suitable to execute the opportunity. The IP owner might not even know that his IP is valuable and exploitable and is therefore not aware of its value. The fund can negotiate to acquire the IP in exchange for cash or equity with a higher negotiation power and keep a high founder share (Qian and Acs 2013). The problem of a lemons market is turned upside down.

Broader implications. Our findings and propositions have implications for the literature on the entrepreneurial process and opportunity recognition (Eckhardt and Shane 2010; Baron and Ensley 2006; Kirzner 1997; Venkataraman 1997; Stigler 1961). First of all, it is intriguing that a fund as provider of primary financial resources can take over the core entrepreneurial task of opportunity recognition. Fund managers are able to do this because of their unique access to information and their cognitive abilities, shaped by prior experiences, knowledge and networks as suggested in extant research. We furthermore show that the search for information can be a central part of the identification of an opportunity (Eckhardt and Shane 2010; Stigler 1961). It has been argued that relative search costs between potential entrepreneurs and specific search techniques influence the ability to recognize an opportunity (Eckhardt and Shane 2010; Stigler 1961). This model, however, has been challenged as it "assumes that people know the outcomes for which they are searching" (Shane 2000, p. 451) and an "opportunity, by definition, is unknown until discovered or created" (Kaish and Gilad 1991, p. 48). Our cases support the former argument and show that search costs are decreased by funds as they constantly scrutinize a certain industry and have deep knowledge about it or as they own proprietary search tools and use data analytics.

In addition, we provide evidence for the related concept of entrepreneurial absorptive capacity, which was suggested by Qian and Acs (2013) in the context of knowledge-based entrepre-

neurship. The entrepreneurial absorptive capacity "allows entrepreneurs to understand new knowledge, recognize its value, and commercialize it by creating a firm" (Qian and Acs 2013, p. 185). It therefore involves the task of absorbing knowledge created by an external individual or organization and the ability to exploit this knowledge. Our results show that fund managers in the opportunity-based investment style have both the related scientific and business knowledge required to do this (Qian and Acs 2013; Cohen and Levinthal 1990). We therefore give evidence for interpersonal knowledge spillovers as the entrepreneurial activity is driven by someone external to the inventor or inventor organization (Qian and Acs 2013).

Last, our findings have implications for the broader entrepreneurship literature. We support the notion brought forward by Murray (1996) that entrepreneurial resources can be "seen as an eclectically sourced stock" (Murray 1996, p. 41). Our results show that funds can systematically build and staff a new venture, involve the inventor based on his importance for the technical development and can even take over the core entrepreneurial task of opportunity recognition. The division of work is thereby dependent on the investment style but also on situation-specific circumstances and technology characteristics (e.g., whether the inventor is willing and able to drive technology development or whether fund-internal technicians can do this). The active involvement of the fund in both commercial and technical matters in our cases therefore represents a portfolio of resources that complements the existing resources bound in the inventor and the technology and that includes access to additional complementing resources in terms of surrogate management, further funding sources or commercial industry partners. Consequently, we agree with Gartner et al. (1994) who suggest that "[t]he 'entrepreneur' in entrepreneurship is more likely to be plural, rather than singular" (Gartner et al. 1994, p. 6). The optimal and efficient combination of resources, skills and experience could lead to a greater probability of success for the new venture (Murray 1996).

Practical implications

Our insights have implications for managers of IP venturing funds, and for managers of other pre-seed and seed fund models as well. An increased understanding of investment models in technology commercialization and their success factors helps rising awareness for different

approaches and is a first step in developing best practices in a risky and uncertain investment environment. Furthermore, IP venturing presents a new form of deal flow so far uncommon in venture capital practice, as commercialization projects are proprietarily channeled and independent of a management team. The assessment of the technology is paramount, as opposed to the focus on management team selection (Baum and Silverman 2004; Shepherd and Zacharakis 2001). This approach also implies that the fund gets access to potential deals that other investors sourcing investment opportunities via pitch contests would not see.

Understanding IP venturing may also be of importance for the providers of technology, i.e., universities or corporations, as they learn about new models for pushing the exploitation of inventions. Whereas technology transfer by universities has mostly been researched in the context of the role and activities of technology transfer offices, our insights into different cases of the technology-based investment style might encourage an increased collaboration with outside investors (Lockett et al. 2005). Universities can thereby outsource the task of technology commercialization and still benefit from proceeds from equity holdings. Alternatively, the findings have implications for the setup and competencies of technology transfer offices at universities.

Limitations and future research

The study is limited to six cases. In order to increase the external validity of the results, a broader range of cases should be investigated, including, for example, fund models in different countries. Future research should also put more emphasis on exited portfolio firms of IP venturing funds and consider realized returns above a certain threshold (e.g., Murray 1996), comparing them with unsuccessful cases in the context of a maximum variation sampling approach. Moreover, our propositions suggesting factors influencing the success of IP venturing projects should be tested in a quantitative study which allows for statistical rather than analytical generalization (Eisenhardt 1989). Thereby we could learn how sustainable returns for the funds actually are.

Furthermore, our study leaves some interesting questions open, providing promising avenues for further research. What are returns at the fund level? How are returns distributed across

portfolios of IP venturing projects? Answers to these questions would provide insights into how successful the funds' approaches to managing risks in this financing stage are across a portfolio of cases. Similarly, it would be interesting to compare survival rates and performance of start-ups created by IP venturing funds with other start-ups.

With regard to the two investment styles identified, it would further be intriguing to investigate differences in return characteristics that might exist between the opportunity-driven and the technology-driven approaches. What are returns on fund level for each investment style? How are returns distributed for different types of IP venturing projects and for different return measures? Are the characteristics of these approaches really binary or do funds exist that mix the two investment styles? What implications would a mix of both investment styles have for risk and return characteristics?

Last, the business model of IP venturing funds should be put in the context of other innovative entrepreneurial financing models which emerged recently (Block et al. 2017). What are the interactions with traditional sources of early-stage financing, such as venture capital or business angels? How does the backing of an IP venturing fund influence the likelihood of obtaining different financing sources at a later stage? How does the existence of financing sources and entrepreneurial networks (such as Silicon Valley) impact the emergence and success of alternative approaches such as IP venturing?

Our study provides the groundwork to further research on the phenomenon of IP venturing funds which not only provide important resources for technology commercialization before and after incorporation of a new venture, but even create entirely new entrepreneurial opportunities from patents lying idle.

2.6. Appendix

Case description – Case A

Invention. Case A deals with the commercialization of a biotech product based on a monoclonal antibody that regulates the production of eosinophils. High levels of eosinophils can be responsible for a number of inflammatory diseases. The original invention was made by a small biotech company in the UK and was in-licensed by a large US pharmaceutical company. The company conducted a Phase I study which was successfully completed, and a Phase II study for the condition of asthma, which failed. Although it was shown in both studies that the drug was safe and biologically active, the company subsequently abandoned the product.

Access to invention. The results of both clinical studies were published and reviewed by the fund manager who had been an executive at another pharmaceutical company active in the respiratory space. Alternative conditions for the molecule were identified and the fund decided to acquire the product from the pharmaceutical company.

Structuring. The fund acquired the IP including, e.g., biological agent, patents, regulatory package and clinical trial results, and in-licensed the original patent from the UK company in 2004. As the IP was acquired, neither the UK company nor the pharmaceutical company participated in the new venture.

Initial activities. The fund managers conducted market studies and narrowed down the two most promising conditions. The start-up was set up and management was recruited in the following two years.

Further investment/ exit: Additional funding was obtained from larger venture capital funds in order to conduct Phase II trials for the identified conditions (in total ~ $78M in two rounds). Shortly thereafter the fund was approached by pharma companies which were interested in the asset. The fund exited the investment through a trade sale with a multiple of >10x after a six-year holding period in 2010.

Case description – Case B

Invention. Case B describes the commercialization of an invention which is the result of 30 years of research of a group of scientists at a UK university. The technology uses polymer beads to clean textiles with only a small amount of water. The commercial idea was to translate this into a washing machine that saves water, energy and chemicals.

Access to invention. The invention was disclosed by the professor who led the research team at the university in 2006, consisting of a half-page description of the findings. This was when the managers of the fund first got in touch with the technology. Through a long-term partnership with the university, the fund gets access to all disclosures, screens them and selects ideas with the potential for a start-up.

Structuring. The initial structure of the new venture is determined by a framework agreement with the university. According to this, equity after transferring the IP was split between the fund (30%), the university (30%) and the inventors (40%). At that point every new spin-off is valued at £750,000 and the fund invests based on this valuation. The first investment of ~ £50,000 for proof of concept work was provided in 2006 (debt instrument).

Initial activities: In cooperation with the university it was decided to apply for a patent. The company was incorporated in 2006 and the IP was assigned to it. The subsequent activities of the funds aimed at challenging the idea and in investing small amounts in order to fail it fast. In the very beginning, the fund drove the development, employing its own scientists and working with the inventors. In 2008, the fund recruited an external CEO through its headhunting function. The CEO recruited the rest of the management team (CTO). The inventor served as a non-executive.

Further investment: To date, the company has raised ~ £60M. The fund invested ~ £10M of that. The seed and Series A round took place in 2008 and 2009 respectively, followed by further financing rounds in 2010 (£3.5M) and in 2013 (£10M). More capital was raised through an IPO in 2014 (~ £28M). The fund has not sold any shares and still holds 16.5% of the equity.

Case description – Case C

Invention. The invention in Case C resulted from research at the School of Medicine at a UK University. The lead inventor, a physicist, worked in the field of magnetic resonance imaging (MRI) and found a new technology for a technique called oxygen-enhanced MRI. A patent was filed in 2008 with support from the university's technology transfer office.

Access to invention. The inventor recognized the commercial potential of the technology. He presented it as a proof of principle project. 10% of the fund is dedicated to these projects and is awarded by the university TTO. The fund gave input on the investment decision and was involved in the project from this point on. Being independent of the TTO, the fund does not have strict exclusivity to potential deals from the university, but does have a right of first refusal.

Structuring. In exchange for the proof of principle investment (~ £100K), the fund gets 15% of the equity of the new venture in the case of start-up creation. The university, as the legal owner of the IP, gets 15% for assigning the IP to the start-up and another 15% in exchange for patent costs, patent filing and other services provided by the TTO.

Initial activities. The focus of the proof of principle project was to prove the commercial value. Software was developed and in conversations with a potential customer the idea of providing imaging service became more concrete. In 2009, the inventor together with the fund decided to create a company. The IP was transferred from the university to the new start-up. The fund provided support in setting up the organization, governance and team of the new venture. One fund manager holds a board seat. In the beginning, an external CEO was recruited; however, cooperation failed shortly afterwards. The inventor was involved as a Chief Scientific Officer but took over as CEO in 2013.

Further investment. In general, the fund tries to invest in later rounds in order to avoid dilution. It also leverages its network to connect the new venture with other investors. To date, the company has raised ~ £ 3M in 5 funding rounds, of which the fund invested ~ £ 1.5M. The

fund holds 30% of the company today and expects that to be diluted to 20% by the time an exit is achieved. The envisaged holding period is >10 years.

Case description – Case D

Invention. The invention commercialized in Case D is based on the work of four researchers in the field of natural gas at the College of Engineering at a US university. The envisaged product is a natural gas compressor using liquids and novel geometries to compress natural gas. The compressor is used to fuel light- and medium-duty commercial vehicles and is more efficient and affordable than conventional reciprocating compressors.

Access to invention. Recognizing the potential of this invention, the research team disclosed it to the TTO of the university. At this time, the technology consisted of the idea and a drawing. A patent was not yet filed. The TTO pre-selected and presented several disclosures to a potential external entrepreneur who eventually selected this technology to start a new venture in 2012. The fund was involved from the beginning because of its strong connection to the university (which is an investor in some of its funds).

Structuring. The initial structure of the new venture is subject to the maturity of the IP and negotiations. The IP, which is owned by the university, was licensed to the start-up in exchange for equity and royalties. Two of the inventors quit their university jobs and became co-founders. The equity at incorporation was split between the founders (61%), the non-founding inventors (5%) and the university (19%).

Initial activities. The founders received first funding through a $100K grant sponsored by the state in 2012. The fund supported them in developing a business plan and in validating market and customer potential of the technology. In 2013, the venture was incorporated and received its first funding by the fund through convertible notes. This initial funding was used to build a prototype. The fund provided several services before and after incorporation, e.g., regarding the organizational setup, reporting and governance of the new venture. Moreover, the fund and the university TTO have assisted in recruiting and building a team. In this case, the con-

tact with the external CEO was established and two of the inventors joined the start-up; one retired shortly afterwards and one is active as CTO of the venture.

Further investment. To date, the venture has raised ~ $2M in three investment rounds. Of this the fund invested ~ $0.8M. Other investors include corporations and angel investors. The fund today holds ~ 20% of the equity and expects to hold 5-10% at the point of exit.

Case description – Case E

Invention. The invention in Case E resulted from 14 years of research at a public research institute in the US. It focused on fuel cell technology in military applications. In line with the fund's investment principles, the IP developed at the institute was complemented by some initial technical validation and proof of concept work.

Access to invention. The fund uses analytics tools to identify inflexion points in the market. In this case, fuel cells were identified as a promising technology and the corresponding market and underlying IP was analyzed. The fund searched for high level IP and contacted IP owners (~ 3-4 different parties). Among them, the fund approached a research institute and triggered the creation of a company focused on the application of fuel cells to smart phones and mobile appliances.

Structuring. The owner of the IP (the research institute) assigned the IP fully to the new venture in exchange for equity (35% of the start-up after incorporation). The remaining 65% was held by the fund.

Initial activities. The new venture was incorporated and the fund committed to invest $2M. The IP was assigned to the new entity. In order to develop prototypes and to validate the design, service agreements with the research institute were set up. One year after incorporation, the inventors joined on a full-time basis. In the beginning, the fund provided several support services: it helped develop a business plan and detailed market studies. The fund provided business support services. Moreover, it heavily supported the recruitment of an executive team focused on commercial know-how. The CEO joined in 2002.

Further investment. Overall, ~ $ 37M was raised in 4 rounds, of which $2M was invested by the fund. Co-investors included venture capital funds and corporate investors. The investment was exited after a 6-year holding period in 2005 via an IPO. At the time of the IPO the fund held ~12% of the equity in the company.

Case description – Case F

Invention. Case F describes the commercialization of a technology for a particle accelerator. The technology was originally intended for a consumer-purchased fan but lay idle for several years. It was patented but there was no commercial prototype. The inventor was the retired owner of a very small and bankrupt tech company which was the legal owner of the patent. Several small and large companies at that time produced such consumer products based on similar technologies, but these products were banned in 2008 because they produced ozone. As a consequence, the consumer market for this technology broke down.

Access to invention. When the demand for the consumer product broke down, the fund started to look for technologies in this field that were owned by companies which could now be expected to struggle. Using its proprietary analytics the fund identified several relevant patents, among them the patent of the small tech company. This very successful analytic approach is based on machine learning algorithms in combination with multi-language dictionaries of technology terms. Because of its small size and efficiency the underlying technology of the small company was assessed to have the largest potential. The fund identified a new application for it, targeting a niche market. The idea was to use this technology to produce small high-quality ion particle accelerators.

Structuring. The patent was licensed by the newly created company. In exchange, the inventor got 10% of the equity of the venture. In 2012, the fund acquired that 10% and the ownership rights for the patent.

Initial activities. A company was set up to commercialize the patent. The fund defined the market and the corresponding product. A corresponding commercial prototype was built by engineers available within the fund and in cooperation with contracted third party providers

such as 3D printing companies. The development took about 2 years. A dedicated team began to build and grow the new venture. An employee of the fund was appointed CEO and ran the company for three years. The inventor was on the technology advisory board. Today, it is a virtual company with strong sales focus.

Further investment/ exit. Overall, ~ $ 0.5M was invested in the new venture by the fund. The fund still holds 100% of the equity and does not intend to sell it in the next years.

III. Conclusion

1. Summary of results

The overarching goal of this thesis is to investigate the phenomenon of patent-based investment funds as an emerging business model in entrepreneurial finance. The thesis consists of two essays each of which addresses different research questions. The first essay sets the ground for a better understanding of the overall business model of patent-based investment funds and its role in the invention-to-innovation process. The essay draws on the knowledge spillover theory of entrepreneurship (e.g., Braunerhjelm et al. 2010; Carlsson et al. 2009; Acs et al. 2004; Glaeser et al. 1992). It introduces patent-based investment funds as intermediaries in the knowledge spillover process which actively decrease knowledge filters and facilitate commercialization. The business model of patent-based investment funds is differentiated along mode, locus and length of technology development and the resulting classification of four commercialization strategies is proposed: "Technology licensing", "IP venturing – early M&A", "IP venturing – long-term incubation" and "IP venturing – extension". In addition, it is suggested that certain dimensions of a set of invention characteristics determine the suitability of patents and patentable inventions for a particular commercialization strategy.

The first essay spans the entire spectrum of commercialization strategies employed by patent-based investment funds. In doing so it introduces IP venturing strategies wherein funds actively create new ventures in order to commercialize patents and patentable inventions (Festel et al. 2015). Funding and support are provided for the new start-up during the holding period. When the investment is exited, income is generated through a trade sale or an IPO rather than through a sale or license of patents or rights thereof (Gredel et al. 2012). This pathway resembles at first sight traditional venture capital; however, it can be clearly differentiated as it is active pre-incorporation (Festel et al. 2015; Festel and De Cleyn 2013) and has a clear focus on patents and underlying technologies. Funds following this approach are referred to as IP venturing funds and are a sub-group of patent-based investment funds.

The second essay explores the business model of IP venturing funds and adds depth to the findings presented in Essay 1. It draws on agency theory and extant literature on the management of agency risks and uncertainty in early stage investing (Gompers and Lerner 2004; Kaplan and Stromberg 2001; van Osnabrugge 2000; Gompers 1995; Sahlman 1990; Fama and Jensen 1983). It is proposed that IP venturing funds decrease agency costs and add value to their portfolio through active business building, including taking over management positions, recruiting a surrogate management team and providing commercial and technical support. In addition, a dichotomy of IP venturing styles is established: Funds following the opportunity-driven investment style take over the entrepreneur's role and trigger opportunity recognition and exploitation. Thereby, agency costs are reduced due to the unity of principal (fund) and agent (entrepreneur). Funds following the technology-driven investment style have a particular focus on commercializing technology out of research institutions. They apply contracting solutions to reduce agency costs as well as valuation and due diligence costs.

2. Theoretical implications

This thesis has several theoretical implications. First, the research presented in the two essays contributes to extant literature on patent and technology intermediaries (Krech et al. 2015; Gredel et al. 2012; Wang 2010; Benassi and Di Minin 2009; Chesbrough 2006b; Elton et al. 2002) as well as on new players in entrepreneurial finance (Block et al. 2017; Festel et al. 2015; Festel and De Cleyn 2013). Essay 1 gives an overview of activities and commercialization strategies of patent-based investment funds spanning the entire spectrum of pathways. Recent literature on patent and technology intermediaries has not always differentiated between players in the market for patents versus the market for technologies (e.g., Krech et al. 2015). By analyzing fund models which explicitly do not only monetize the legal right of a patent, the role of patent-based investment funds in the invention-to-innovation process can be examined. It is shown how these funds can actively facilitate this transition. The importance of providing funding in the early stages of technology development in order to develop and de-risk the invention is highlighted, which implies that fund models take significant financial risks. Patent-based investment funds are therefore not only a way for existing firms to gener-

ate proceeds from patents to finance and grow their ventures as proposed by Block et al. (2017), but they actively finance entrepreneurial activity themselves.

Moreover, extant research has mainly focused on the licensing pathway to commercialize patents (Krech et al. 2015; e.g., Gredel et al. 2012; Benassi and Di Minin 2009) whereas Essay 1 shows that this is only one of the possible commercialization pathways. The essay presents strategies based on the creation of a new venture around patents and patentable inventions. The start-up creation pathway and its funding have so far been in the centre of entrepreneurial finance literature, which however mainly focused on business models providing funding at later stages after incorporation. The findings presented in the first essay therefore connect the research streams of technology intermediaries and entrepreneurial finance. Essay 2 adds more depth to our knowledge of IP venturing as a new business model in the pre-incorporation phase of a venture. Specifically the proposition with regard to a dichotomy in investment styles expands the prevailing concept of IP venturing as a technology transfer mechanism triggered by technology push (Festel et al. 2015). The approach described as opportunity-based investment style has so far not been investigated by academic research.

In addition to contributing to literature dealing with players in the context of patent and technology intermediation and new players in entrepreneurial finance, each of the essays draws on extant theory to embed the results emerging from the qualitative data. Through the comparison of findings with literature, existing theory can be expanded or refined (Eisenhardt 1989). Consequently, the two essays have additional contributions to related literature streams: the knowledge spillover theory of entrepreneurship and the management of high risk early-stage investments. In addition, broader implications refer to selected aspects of entrepreneurship and technology transfer literature.

The findings of Essay 1 contribute to the knowledge spillover theory and the knowledge filter model. They provide evidence for the division of labor between inventor and commercializer, which is an important assumption in the KSTE (Ghio et al. 2015; Block et al. 2013; Acs and Sanders 2012; Braunerhjelm and Svensson 2010; Acs et al. 2009a). Moreover, it is shown that patent-based investment funds' activities can decrease institutional knowledge filters as well

as competency and financial constraints. Also, the importance of networks in overcoming knowledge filters in the knowledge spillover process (Hayter 2013) is underlined. Both essays provide evidence for the concept of entrepreneurial absorptive capacity (Qian and Acs 2013). Patent-based investment funds can take over or enhance this capacity as they are able to understand and recognize the value of new knowledge created by an external individual or organization, and trigger commercialization. Funds can thereby exploit otherwise unrecognized opportunities.

The second essay proposes success factors of IP venturing funds and thereby adds to our understanding of how funds manage high risk and add value to a portfolio of early stage technology commercialization projects to increase return (e.g., Gompers et al. 2005; Kaplan and Stromberg 2001; van Osnabrugge 2000). This fills a research gap that exists in the field of emerging players in entrepreneurial finance and their approaches to dealing with especially pronounced risks at this stage. It is shown that IP venturing funds are very active trying to "build winners" (Baum and Silverman 2004, p. 428) in the post-investment phase. Additionally, novel contracting approaches in the technology-based investment style are explored implying that funds act as contractors in order to reduce agency costs and keep due diligence low. They circumvent an early selection of winners and focus on setting the stage for capital-efficient monitoring and development activities. Alternative approaches to handling agency risks are supported, e.g., the importance of social capital (Eckhardt and Shane 2010) in the context of surrogate management teams. Last, self-financing is employed (Eckhardt and Shane 2010) in the opportunity-based investment style where the fund identifies the opportunity, thereby joining entrepreneurial and financing resources and resolving the principal agent relationship.

Last, both essays have broader theoretical implications for research in entrepreneurship and technology transfer. Essay 1 refines and expands prior literature on the link between commercialization modes and the nature of the invention (Block et al. 2013; Festel 2013; Festel and De Cleyn 2013; Eckhardt and Shane 2010; Shane 2001a; Henderson 1993). The set of invention characteristics proposed for technology licensing shows particularly well that very strong

pre-conditions have to hold to make this commercialization path suitable. Further, the findings presented in Essay 2 have interesting implications with respect to the entrepreneurial process and opportunity recognition (Eckhardt and Shane 2010; Baron and Ensley 2006; Kirzner 1997; Venkataraman 1997; Stigler 1961) as fund managers are shown to be active in the systematic search for and identification of opportunities. Finally, the notion of entrepreneurial resources "as an eclectically sourced stock" (Murray 1996, p. 41) is supported.

3. Practical implications

Research on patent-based investment funds has implications for practice which are important for the development of a more efficient capital market for inventions. Despite the currently small size and investment volumes of funds investing in patents and patentable inventions compared to asset classes such as venture capital or private equity, the findings presented in the two essays reveal interesting insights into what it actually takes to connect market participants in today's inefficient markets for technology (Arora and Gambardella 2010; Troy and Werle 2008; Gambardella et al. 2007; Shane 2003; Arora et al. 2001; Teece 1986), to implement an effective division of labor along the invention-to-innovation process (Acs and Sanders 2012; Brouwer 2002; Schumpeter 1934) and to contribute to filling the equity gap in the earliest stages of technology commercialization whilst managing risks so that a return for investors can be generated (Maia and Claro 2013; Mason and Harrison 2004; Auerswald and Branscomb 2003). Although results cannot be conclusive, this thesis opens room for discussing crucial considerations when implementing a patent-based investment fund.

First of all, the attempt at providing a clear definition and improving the understanding of patent-based investment funds' activities informs all stakeholders of an invention capital market. Especially the lack of a clear differentiation between funds focusing on the monetization of pure patent rights and funds active in technology transfer (Fischer and Henkel 2012) can lead to misunderstandings and a general skepticism about patent-based investment funds. This certainly impedes a trustful cooperation between technology providers and funds and deters the interest of investors. With respect to IP venturing funds, start-up creation based on IP is mostly associated with university spin-offs by academics and practitioners alike. There-

fore, our findings on the opportunity-based investment style, which is based on the extension of more mature IP in different applications, are particularly valuable for practice.

Second, although our essays do not allow conclusions with regard to the overall performance of patent-based investment funds, the research demonstrates characteristics of particularly successful commercialization projects. Findings – and especially the success factors proposed in Essay 2 – are therefore highly relevant for managers of patent-based investment funds as well as for players who plan to adopt similar business models in the future such as, for example, NPEs expanding into technology commercialization (Donegan 2015). More generally, they also offer interesting insights for managers directly active in external commercialization of companies or universities (e.g., TTOs) as well as in early-stage investment vehicles such as proof of concept centers or seed funds (Ayoub et al. 2016). They are a first step towards a set of best practices and might help to critically scrutinize existing fund models. This might in the end help to increase commercialization successes and returns. Some of the approaches presented in the essays might also be transferable to existing business models such as venture capital. Implications with regard to the following topics will be highlighted: commercialization pathways, resources and competencies, funds size as well as sourcing and structuring approaches.

Managers active in IP commercialization in general and in patent-based investment funds in particular should be aware of the full spectrum of commercialization pathways highlighted in the essays of this thesis and consider path-specific activities as well as investment characteristics. The set of invention characteristics explored in Essay 1 should help commercializers of technology to make better decisions regarding the most suitable commercialization pathway. Players active in technology licensing should be especially sensitized for the specific preconditions required to achieve a successful exit, including the need for advancing a nascent technology before licensing it to an incumbent. Difficulties in the development and transfer of a technology in the case of technology licensing are even more pronounced for funds active between the creator of the technology and the final licensor. Moreover, attention should be paid to different risk and return characteristics of commercialization strategies, e.g., between technology licensing and IP venturing, but also between IP venturing approaches. These dif-

ferences could allow for diversification within patent-based investing leading to a more desirable risk/ return mix when combining different strategies.

In addition, patent-based investment funds have very high requirements with regard to resources and competencies of their fund managers. Industry expertise and experience in the earliest phases of technology commercialization are especially crucial for the success of projects. These attributes allow the fund managers to provide the non-financial support during a holding period and – in the case of IP venturing – the provision of business building activities. The criterion regarding resources and competencies is especially pronounced for funds employing the opportunity-based IP venturing investment style: the ability to discover new entrepreneurial opportunities on the basis of sleeping patents is closely tied to the human resources of the fund. In addition to experienced and knowledgeable fund managers, fund internal technical resources and shared administration services can be necessary depending on the investment strategy of the fund. These resources resemble an incubator rather than traditional venture capitalists (Bøllingtoft and Ulhøi 2005). Furthermore, fund managers must be well networked. This is important, for example, for the sourcing and evaluation of patents and patentable inventions, identification of surrogate management or access to further financing for portfolio companies.

Leveraging own competencies and networks, entrepreneurial resources can be eclectically selected for particular commercialization projects. In the case of IP venturing, a critical success factor is the identification and selection of a surrogate management team, especially in areas which are not renowned centers for entrepreneurial activity. Fund managers should rely on experienced managers with industry know-how, rather than fresh graduates from university. In the case of technology licensing, external providers can push forward technology development. This could lead to a higher division of work in the entrepreneurisl process and an improved matching of capabilities. Division of labor can, however, not always be clear cut. In all commercialization pathways, the inventor should be included for technical aspects when required. This primarily depends on the availability and interest in commercialization of the inventor, the availability of alternative technical experts in the field and the complexity of the technology. When required, the inventor should be sufficiently incentivized through a share

in the commercialization proceeds. Funds should therefore review existing incentive schemes based on a high upfront payment for technology providers.

Another implication of our findings for setting up IP venturing funds is that a critical fund size is necessary. With respect to the high requirements for competencies of fund managers, management fees that allow for an appropriate compensation of high caliber managers must be earned. More importantly, however, the fund should be able to follow the money in order to avoid dilution and losing influence too early. The smallest IP venturing fund analyzed in Essay 2, for reference, had a size of £32M. This success factor is highly relevant for other fund models active in the pre-seed and seed stages of technology commercialization. The suggested minimum size lies significantly above fund sizes reported for UK seed venture capitalists and even above the £20+M proposed by Murray (1994) and Murray (1999) for a viable seed financing model. Similarly, the business model of PoCCs in the US, which is restricted to very small funding sums in the concept and prototype development (Bradley et al. 2013), might deserve scrutiny.

Our findings also inform fund managers about novel sourcing and structuring approaches. Like familiar investment models such as venture capital, relationships and networks play an important role in generating deals. Moreover, our analysis of IP venturing funds reveals two new approaches based on proprietary sources. First, deal generation is automated through formal partnerships with universities, opening up access to all inventions disclosed to the institution. Second, proprietary data analytics tools are used to examine public patent data and funds actively search for undervalued IP assets. While the latter approach on its own is closely tied to the highly skilled human resources of the funds, the two sourcing approaches could be combined and extended. For example, patent data analytics could complement search processes of technology-based IP venturing funds and other patent-based investment funds. Moreover, exclusive partnerships including pre-set terms with companies or research institutions other than universities are a potential extension.

These sourcing approaches have additional implications for other entrepreneurial finance players. In contrast to traditional venture capital and other post-incorporation financing ap-

proaches, patent-based investment funds source deals independent of an entrepreneur or existing management team. Full focus lies in the quality of patents and patentable inventions rather than the evaluation of the abilities of the managers (Baum and Silverman 2004). This opens up a new deal flow as fund managers are independent of proposals made by entrepreneurs or the availability of a management team. The approach presents a chance for seed stage investors who might face constraints in the supply of good investment opportunities (Murray 1994). It might be interesting for other players in the field of early-stage investing to partly adopt such approaches.

Apart from implications for a general acceptance and improved setup of patent-based investment funds, the knowledge about patent-based investment funds has more concrete implications for technology providers. It might encourage them to start or to intensify cooperation with funds and thereby increase division of labor in the market for technology. As the findings of this thesis show, very specific resources and competencies are required for successfully commercializing patents and patentable inventions through technology licensing and start-up creation. Instead of building up these resources, producers of new knowledge such as universities or companies aiming at commercializing non-core technologies can leverage patent-based investment funds as commercialization partners. In the context of universities, funds might cooperate more closely with TTOs as shown in the technology-based IP venturing cases. By facilitating access to inventions or establishing more formal partnerships, technology providers could not only accelerate the emergence and activity of patent-based investment funds and foster division of labor in the commercialization process but also participate in the upside of a commercialization project and increase their return on R&D.

Last, the results indicating the active contribution of patent-based investment funds in transferring inventions to economically measurable innovation highlight the desirable impact of these players in our knowledge-based economy. They not only support technology transfer but also create entirely new opportunities based on existing research results. In that way, patent-based investment funds present a new way to increase the exploitation of patents and technologies which would otherwise remain unused and make the process more efficient.

Still, some of the impediments to an invention capital market remain. For example, a fund that raised a sufficiently large amount would theoretically prefer to make later, larger and less risky investments instead of dealing with the high failure rates in the very early stages as described by Murray (1999). Moreover, investors are skeptical of new fund models with little known investment characteristics and timelines which can be much longer than what they are used to from their experiences with venture capital. Therefore, policy makers should consider actively driving the setup of new patent-based investment funds, especially in the context of universities and public research institutions. Like government-backed seed and venture capital funds this might also include public funding. Due to the economic impact of the funds' activities this is especially relevant for regions where venture capital and other sources for early stage financing are scarce, where universities are not yet very active in their technology transfer efforts and where networks linking technologies with surrogate managers are not very strong. Such an innovation-enhancing policy agenda could foster regional growth and get private investors increasingly used to new investment characteristics.

4. Future research and outlook

The research presented sets the groundwork for further investigations of new business models in the field of technology intermediation, entrepreneurial finance and patents as assets in general as well as patent-based investment funds. The essays are two of very few extant studies on this new phenomenon. Insights therefore are a starting point for extending this thesis and open several avenues for further research

First, the phenomenon of patent-based investment funds should be examined from different perspectives in order to increase the validity and reliability of the results. For example, since the two essays draw mainly on funds active in the US and Europe, emerging fund models in Asia, where legal conditions and entrepreneurial mindset might be different, could be examined. Moreover, including the point of view of the inventor would give additional insights into the division of labor in the commercialization process as well as the motivation, entrepreneurial capabilities and incentives needed to make commercialization efforts of patent-based investment funds more successful. Future studies should also focus on the exit of a commercial-

ization project by investigating preferences of companies licensing or acquiring technologies from patent-based investment funds and by analyzing cases of exited investments with realized returns above a certain threshold.

Second, the distribution of shares in commercialization projects and the resulting returns and compensation for inventors, investors and management should be investigated further. Examining the factors that influence this distribution would generate interesting insights into the respective bargaining power of involved stakeholders in the presence of an intermediary (Acs and Sanders 2012). Apart from the strength of legal protection these factors might include considerations such as regional availability of financial resources as well as human resources which can be leveraged as surrogate management. Findings with regard to an optimal distribution of rents would have important normative implications and facilitate the setup of new funds, e.g., in the context of corporate or university spin-offs.

Last, future quantitative research should investigate the performance of patent-based investment funds at both the deal level and the fund level. Insights into returns and return distributions for different pathways and investment styles will shed light on the sustainability of the business model of patent-based investment funds. This will be particularly interesting for technology licensing where preconditions are very specific. With regard to variables influencing the success of patent-based investment funds, the propositions made in the essays should be tested using a large sample which allows for statistical generalization. Only when certain fund models prove successful in the long run and stakeholders participate appropriately, a virtuous cycle will commence that leads to more funds available for early-stage development, increased commercialization, economic growth and finally more inventions.

The objective of this thesis is to enhance the understanding of patent-based investment funds, their role in the invention-to-innovation process and the factors in their success. The thesis contributes to research on new business models in the context of technology intermediaries, entrepreneurial financing models and patents as assets as well as to extant literature on the knowledge spillover theory of entrepreneurship and the management of agency risk. The increased knowledge of the phenomenon of patent-based investment funds is also of interest to

practitioners. Simultaneously, the thesis presents important reference points for future research. It should encourage practitioners and academics alike to further pursue their efforts towards defining successful patent-based investment fund models in an emerging invention capital market.

Eidesstattliche Erklärung

Ich erkläre an Eides statt, dass ich die bei der promotionsführenden Fakultät für Wirtschaftswissenschaften der Technischen Universität München, zur Promotionsprüfung vorgelegten Arbeit mit dem Titel:

Patent-based investment funds as an emerging business model in entrepreneurial finance

am TUM Lehrstuhl für Entrepreneurial Finance 2 unter der Anleitung und Betreuung durch Prof. Dr. Reiner Braun ohne sonstige Hilfe erstellt und bei der Abfassung nur die gemäß § 6 Abs. 6 und 7 Satz 2 angegebenen Hilfsmittel benutzt habe.

- Ich habe keine Organisation eingeschaltet, die gegen Entgelt Betreuerinnen und Betreuer für die Anfertigungen von Dissertationen sucht, oder die mir obliegenden Pflichten hinsichtlich der Prüfungsleistungen für mich ganz oder teilweise erledigt.
- Ich habe die Dissertation in dieser oder ähnlicher Form in keinem anderen Prüfungsverfahren als Prüfungsleistung vorgelegt.
- Die vollständige Dissertation wurde nicht veröffentlicht.
- Ich habe den angestrebten Doktorgrad noch nicht erworben und bin nicht in einem früheren Promotionsverfahren für den angestrebten Doktorgrad endgültig gescheitert.

Die öffentlich zugängliche Promotionsordnung der Technischen Universität München ist mir bekannt, insbesondere habe ich die Bedeutung von § 28 (Nichtigkeit der Promotion) und § 29 (Entzug des Doktorgrades) zur Kenntnis genommen. Ich bin mir der Konsequenzen einer falschen Eidesstattlichen Erklärung bewusst. Mit der Aufnahme meiner personenbezogenen Daten in die Alumni-Datei der TUM bin ich einverstanden.

München, den 30. Mai 2017: .....

Andrea Röhm

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