FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

Initiation of knowledge and technology transfer from academia to industry: Opportunity recognition and transfer channel choice

Matthias Huegel | Philip Doerr | Martin Kalthaus

JENA ECONOMIC RESEARCH PAPERS · # 2023-002

The JENA ECONOMIC RESEARCH PAPERS
is a publication of the Friedrich Schiller University Jena, Germany (www.jenecon.de).

Initiation of knowledge and technology transfer from academia to industry: Opportunity recognition and transfer channel choice

Matthias Huegel*[1], Philip Doerr[1], and Martin Kalthaus[1]

[1]Friedrich Schiller University Jena, Department of Economics, Carl-Zeiß-Straße 3, 07743 Jena, Germany

January 18, 2023

Abstract

The transfer of knowledge and technology from academia to industry is usually understood as a process. While previous research focuses on phenomena along the process and its outcomes, the starting point of the process – the initiation of a transfer activity – remains unstudied. We provide first empirical insights on the initiation of the transfer process and conceptualize this initiation as a simultaneous recognition of a transfer opportunity and the choice of a transfer channel. We focus on Science-Industry collaboration, Intellectual Property Rights and spin-off creation as relevant channels. We use survey data from 1,149 scientists from the German state of Thuringia and utilize seemingly unrelated regressions to account for selection and multiple channel choices in our econometric approach. Our results show a positive relationship between scientists' probability to recognize a transfer opportunity and different kinds of prior knowledge. Contrary to our expectation, scientific quality reduces the likelihood of recognizing a transfer opportunity. For the choice of the transfer channel, the results show a positive relationship between choosing the spin-off channel and risk willingness, as well as basic research. Applied research increases the likelihood to choose Intellectual Property Rights as a channel. Furthermore, role models are positively associated with these two channels.

Keywords: Transfer Process; Transfer Initiation; Opportunity Recognition; Transfer Channel; Science-Industry Collaboration; Intellectual Property Right; Academic Spin-off

JEL Classification: L26, O31, O33, O34

*Corresponding author.

E-mail addresses: matthias.huegel@uni-jena.de, philip.doerr@uni-jena.de, martin.kalthaus@uni-jena.de.

Acknowledgments: Funded by the Thuringian Ministry for Economic Affairs, Science and Digital Society. We are grateful for discussions by and with Susanne Beck, Uwe Cantner, Johannes Carl, Lukas Dreier, Chang Gao, Maximilian Goethner, Ana María Gómez-Aguayo, H. C. Kongsted and Indira Yarullina, as well as participants at the Jena Economic Research Workshop, the 18th International Schumpeter Society Conference 2021, the WICK#9 PhD Workshop, Complexity and Knowledge 2021, the EuSPRI 2022 and DRUID22.

1 Introduction

The transfer of academic research into application, so-called knowledge and technology transfer (KTT), fosters innovation, economic activity and can contribute to solutions to grand societal challenges (Bornmann, 2013; Fini et al., 2018; George et al., 2016a; Siegel et al., 2003). The KTT does not take place instantaneously but is rather a process that starts with knowledge generation in academia and ends with its application outside academia (Fabiano et al., 2020; Siegel et al., 2004; Wood, 2011). Previous research in one larger stream of literature examines phenomena along the process, especially barriers and facilitators (Bozeman et al., 2015; Perkmann et al., 2021; Perkmann et al., 2013). Another stream of literature focuses on the end of the process, i.e. the transfer outcomes and impacts of the transferred knowledge and technologies (e.g. Abreu & Grinevich, 2013; Audretsch et al., 2012; Bonaccorsi et al., 2014; de Fuentes & Dutrénit, 2012; D'Este et al., 2019). However, the start of the process, the initiation of KTT, has been mostly neglected, despite its importance in understanding if and how transfer takes place and how to mobilize unused transfer potential.

Bar-Zakay (1971, p. 324) already emphasized in his KTT model that "[a] prerequisite for any case of [knowledge and] technology transfer is the existence of an (unrecognized) opportunity for technology transfer." Even though it seems immanent that an opportunity for KTT needs to be recognized to initiate the transfer process, research on this phenomenon has remained absent over the past decades. While Battistella et al. (2016) acknowledged that the difficulty in initiating transfer lies in recognizing a transfer opportunity, research on how transfer opportunities are recognized is missing. While some scholars focus on the intention to conduct KTT (e.g. Goethner et al., 2012; Huyghe & Knockaert, 2015), the intention does not require a recognized opportunity. Furthermore, the initiation of KTT does not only require the recognition of a transfer opportunity but also the choice of a transfer channel to follow-up on the opportunity. Several channels exist for KTT (Abreu & Grinevich, 2013; Fabiano et al., 2020; Haeussler & Colyvas, 2011), but they differ in their degree of formality, risk and reward structure, relevance for industry and other characteristics (Arza, 2010; D'Este & Patel, 2007; OECD, 2013; Perkmann & Walsh, 2009). The choice of the KTT channel is therefore an important decision in the initiation of the transfer process. Previous research has tried to retrospectively explain the choice of a KTT channel after the transfer was completed (e.g. Abreu & Grinevich, 2013; D'Este et al., 2019; Landry et al., 2010) but not at the initiation of the transfer process. A detailed understanding of the initiation of the transfer process gives insights on why some scientists recognize a transfer opportunity while others do not and what influences their decision how to pursue the opportunity. Furthermore, such insights allow for the contextualization of research on phenomena along the transfer process and on transfer outcomes, which are usually analyzed retrospectively and suffer from survival bias.

Given the lack of understanding of the initiation of the KTT process, we provide insights on, first, the antecedents of scientists' recognition of a transfer opportunity to commercialize research and, second, which factors influence scientists' choice of a KTT channel. We conceptualize the initiation of the KTT process as a simultaneous event encompassing the recognition of a transfer opportunity and the accompanying choice of a transfer channel. We build on research on entrepreneurial opportunity recognition (e.g. Ardichvili et al., 2003; Baron, 2007; George et al., 2016b; Mejri & Umemoto, 2010; Shane, 2000, 2001) and adapt and generalize it for the

KTT. For the channel choice, we consider the three most frequent and economically relevant KTT channels: Science-Industry (S-I) collaboration, disclosure of Intellectual Property Rights (IPR) and spin-off creation. We utilize previous findings from retrospective analyses on channel choices (e.g Abreu & Grinevich, 2013; Haeussler & Colyvas, 2011; Landry et al., 2010) to derive potential factors that are relevant for the choice at the initiation of the transfer activity. We center our analysis around the individual scientist and derive hypotheses on the antecedents for the opportunity recognition and the choice of the transfer channel.

To gain empirical insights into the transfer initiation and to test our hypotheses, we developed a novel online survey. We surveyed scientists in the German state of Thuringia between December 2019 and January 2020. Our sample of respondents from universities and research institutes is representative for Germany. Since the transfer initiation consists of the simultaneous opportunity recognition and the KTT channel choice, we need to account for the selection into recognizing a transfer opportunity. To account for a potential selection bias, we propose two novel exclusion restrictions. Furthermore, we need to account for the possibility that multiple KTT channels can be chosen to realize the transfer opportunity. Our empirical strategy builds on Seemingly Unrelated Regressions (SUR) (Roodman, 2011), which allows us to simultaneously estimate a selection equation for the opportunity recognition and outcome equations for each KTT channel. Furthermore, the SUR allows us to assess how different channels relate to each other.

Our results show that fewer than half of the surveyed scientists recognized a transfer opportunity. Decisive for such a recognition is prior knowledge, either gained by academic or non-academic work. However, scientists who produce high-quality research are less likely to recognize an opportunity. For the channel choice, the scientist's research orientations show heterogeneous influences across the channels. Furthermore, risk-willingness is highly relevant to the choice of spin-off channel. Role models have a positive influence on the choice of the IPR and spin-off channel but a negative influence for S-I collaboration. These findings provide first empirical insights on the initiation of KTT and the full transfer potential. The insights on the characteristics that influence an opportunity recognition, as well as the factors that are decisive for the channel choice, can be used not only to refine existing theoretical models on the transfer process but also to guide policy makers. Additionally, we contribute to the growing literature devoted to the choice of KTT channels. While other scholars took a retrospective view from transfer implementation (e.g. Abreu & Grinevich, 2013; D'Este et al., 2019; Haeussler & Colyvas, 2011; Landry et al., 2010; Llopis et al., 2018), we capture the recognition directly which overcomes a survival bias in previous analyses.

In the following Section 2, we conceptualize the transfer initiation and derive hypotheses for the opportunity recognition as well as the choice of KTT channel. In Section 3 we discuss our data and empirical approach followed by the results and robustness tests in Section 4. We discuss and conclude in Section 5.

2 Initiating the knowledge and technology transfer process

2.1 Conceptualizing the initiation phase

A precursor of KTT is the creation of knowledge (Graham et al., 2006; Stephan, 1996). However, the subsequent knowledge transfer from academia to industry does not occur automatically. It requires that scientists deliberately engage with industry through activities which transfer knowledge (Bercovitz & Feldman, 2006; Louis et al., 1989). Although knowledge is considered a public good and sharing is a common procedure in scientific discourse (Gerbin & Drnovsek, 2020), the logic behind the use of research results for potential commercial exploitation is fundamentally different (Dasgupta & David, 1994). For the scientists, acting within academia and industry is subject to conflicting logics (Sauermann & Stephan, 2013) and evokes tensions that have to be managed and balanced (Ambos et al., 2008; Cantner et al., 2021). Especially at the beginning of the KTT process, these tensions are relevant for the scientists to engage in transfer in the first place.

KTT is usually understood as a process (e.g. Fabiano et al., 2020; Maresova et al., 2019) which can be separated into distinctive, successive phases (e.g. Bradley et al., 2013; Siegel et al., 2003; Wood, 2011; Zuniga & Correa, 2013). The starting point of every KTT process is its phase of initiation, which includes the recognition of a transfer opportunity and the choice of a transfer channel. The process ends with the integration of the knowledge and technology by the recipient (Battistella et al., 2016). In most conceptualizations of the KTT process, the decisive step from research activity to the pursuit of transfer activity is neglected or not conceptualized. Vohora et al. (2004) is among the few who, in the context of spin-off creation, discuss the recognition of an opportunity as a critical juncture from doing research to being engaged in transfer activity. However, they do not investigate what influences a scientist's recognition of a transfer opportunity. In the context of S-I collaboration, Philbin (2008, p. 499) refers to a "collaboration opportunity landscape" where scientists would, based on their research, need to provide technical solutions that might contribute to firms' product or service development. Opportunity recognition would require an alignment of such technical solutions with market trends.

At the beginning of the KTT process stands the individual scientist and their research results from which transfer opportunities can be derived (Ndonzuau et al., 2002). The initiation of the transfer process is the recognition of the transfer opportunity. Borrowing from research in entrepreneurial opportunity recognition (e.g. Ardichvili et al., 2003; Baron, 2007; Shane, 2001), we define a transfer opportunity as an idea based on the scientist's research for which they see potential in application outside the academic context. This opportunity can lead to financial or non-financial rewards for the individual scientist or their institution, either through direct research commercialization or indirectly through facilitated access to additional resources. The recognition of such a transfer opportunity is a cognitive process that initiates the KTT process, regardless of whether the pursuit of the opportunity commences and whether the transfer is accomplished. To discover such a transfer opportunity, the individual has to scan research results for their commercial as well as their intellectual potential to translate scientific results into industrial application (Etzkowitz, 1998). It requires from the scientist that they envision and conceive potential industrial applications, which constitute the start for the conversion of knowledge into economic value (Sousa-Ginel et al., 2021; Zahra et al., 2007). This perspective is frequently coined science push (Callaert et al., 2015; D'Este et al., 2019; Nemet, 2009; Walsh, 1984). Alternatively, a transfer opportunity can also be triggered by an industry pull, where industry actors with specific application-oriented problems seek knowledge and expertise from academia and approach scientists to transfer their knowledge (D'Este et al., 2019; Nemet, 2009; Walsh, 1984). In any case, a scientific discovery paves the way for a potential transfer endeavor. Thereby, the transfer opportunity recognition is the first critical juncture in the overall KTT process that needs to be overcome for the actual initiation of the process (Siegel et al., 2003; Vohora et al., 2004). Thus, the process of KTT starts with the scientist's recognition of transferable research results into industrial application.[1]

The recognition of a transfer opportunity is necessary but not sufficient for KTT because the transfer also requires the choice of a transfer channel through which transfer will take place (e.g. Abreu & Grinevich, 2013; D'Este et al., 2019; Ponomariov & Boardman, 2012). In the initiation phase of the transfer process, the recognition of a transfer opportunity coincides with the choice of transfer channel through which the opportunity can be realized. The choice of the transfer channel is therefore a decision that takes place simultaneously with the transfer opportunity recognition. Thereby, the channel through which the transfer is realized is inherently connected to the opportunity that is recognized and to scientists' personal and research characteristics.[2] For example, the discovery of a new algorithm would not be subject to patent protection, but it could be developed into a product by the scientist in a spin-off or in collaboration with industry.

Multiple transfer channels are identified in the literature and can be differentiated by several typologies, e.g., in terms of formality (Bercovitz & Feldman, 2006), risk (Arza, 2010) or the benefits for scientists inherent in the engagement within the transfer channel (de Fuentes & Dutrénit, 2012). The most frequent and economically relevant transfer channels for research commercialization are S-I collaborations, protection and commercialization of IPR and the creation of academic spin-offs (Leitner et al., 2021). Transfer via these channels contains a commercial character either in a narrow sense by selling research results or in a broad sense by co-producing or enabling access to research results to non-academic recipients such as industrial actors. The transfer can lead to a direct economic impact on companies and subsequently on industries, regions or national economies. For the scientists, engaging in these transfer channels can result in scientific and financial returns (Lam, 2011). The transfer channels are associated with different risk-reward trade-offs, and the scientists have to decide upon them. To continue with the above example, commercializing the discovered algorithm with an industry partner will not only have lower risks but also lower rewards than if the scientist founds their own firm. In the literature, the factors that influence the choice of a transfer channel have only been retrospectively analyzed based on the final outcome of the transfer activity (D'Este et al., 2019; Llopis et al., 2018).

[1] It is important to disassociate transfer opportunity recognition from intentions towards KTT. In contrast to opportunity recognition, intentions, e.g. entrepreneurial intentions, are considered as a state of mind directed towards a specific behavior (Bird, 1988). While there is, for example, a relationship between entrepreneurial intention and entrepreneurial behavior (Goethner et al., 2011), we do not consider a transfer intention as a necessary prerequisite for opportunity recognition. In the case of an existent transfer intention, it is formed before the opportunity recognition according to action theory (Achtziger & Gollwitzer, 2018; González-López et al., 2021), but an opportunity might not be recognized and the transfer process not initiated.

[2] While it is widely acknowledged that the initially chosen channel can be subject to change along the overall transfer process (e.g. Hayter et al., 2020; Schaeffer et al., 2020), the scientist's first channel choice is associated with the transfer opportunity recognition at the beginning of the transfer process.

In the following, we focus on potential antecedents for the initiation phase. First, we derive a set of hypotheses to empirically test antecedents of transfer opportunity recognition. We derive our hypotheses from the literature on opportunity recognition in entrepreneurship (e.g. Ardichvili et al., 2003; Baron, 2007; George et al., 2016b; Mejri & Umemoto, 2010; Shane, 2000, 2001) and generalize it for KTT from academia to industry. Second, we derive a set of hypotheses that test the factors influencing the choice of a transfer channel among the scientists who have an opportunity recognition. For the choice of a transfer channel, we draw on the literature regarding scientists' transfer engagement, which provides several factors that allow for the establishment of potential relationships for the choice of the transfer channel (e.g Abreu & Grinevich, 2013; D'Este et al., 2019; Landry et al., 2010). Our approach to conceptualizing the initiation stage of the KTT process allows us to explain, first, why some scientists recognize a transfer opportunity while others do not and, second, what influences the choice of the transfer channel for the subsequent pursuit of the transfer opportunity.

2.2 Antecedents for the transfer opportunity recognition

Central to the initiation of the transfer process is the recognition of a transfer opportunity based on research activity and outcomes. Such recognition is a cognitive process that can be influenced by several factors. We argue in the following that prior knowledge possessed by the scientist can be such a factor. Furthermore, the quality of the research results can influence the recognition of an opportunity, since the higher the quality of research results, the greater can be the opportunities for its application. Lastly, interaction with economic actors can be influential in understanding and recognizing the relevance of industrial application of the generated scientific results. In the following, we derive hypotheses for potential relationships of influential antecedents for the recognition of a transfer opportunity.

Prior knowledge

Prior knowledge is an important antecedent for the recognition of a transfer opportunity, as shown in the literature about entrepreneurial opportunity recognition (e.g. George et al., 2016b; Mejri & Umemoto, 2010; Shane, 2000). Prior knowledge reflects the sum of an individual's knowledge at a given point in time (Arentz et al., 2013). Shepherd and DeTienne (2005) show that the more prior knowledge an individual possesses, the more capable they are to recognize important connections between concepts, which in turn increases the ability to recognize transfer opportunities. Individuals who possess a wide range of prior knowledge and experience are inclined to recognize opportunities characterized by problem-solving and economic value (Hsieh et al., 2007). Especially multiple domains of knowledge and experience increase scientists' ability to recognize transfer opportunities (Cliff et al., 2006; Corner & Ho, 2010). In particular, scientists can accumulate knowledge both from their academic work and from other professional activities, such as work experience outside academia. The knowledge scientists acquire in their academic work is usually highly specialized in a specific research field and results from their research skills and techniques (de Grande et al., 2014). Additionally, scientists might be endowed with non-academic knowledge gained through work experience outside the academic sector (Gulbrandsen & Thune, 2017). Such knowledge contains work practices, market or customer knowledge and other knowledge related to economic activity. Both types of prior knowledge, academic and non-academic, can influence opportunity recognition.

An increasing body of research shows that scientists' prior academic knowledge is positively associated with their KTT activity (e.g. D'Este et al., 2019; Haeussler & Colyvas, 2011; Landry et al., 2007). Prior academic knowledge also positively affects the frequency of such engagements (Tartari & Breschi, 2012), as well as the variety of knowledge transfer channels used for its implementation (D'Este & Patel, 2007; Iorio et al., 2017). The accumulation of research activity and output increases scientists' academic knowledge resources that they can "sell" (Louis et al., 1989). Also, a larger pool of prior knowledge increases the options for knowledge recombination and subsequently the recognition of transfer opportunities. According to the entrepreneurship literature, individuals only recognize entrepreneurial opportunities that are related to their prior knowledge (D'Este et al., 2012a; Shane, 2000). For scientists, this means that a larger body of academic knowledge yields a higher chance of recognizing a transfer opportunity. In line with the high relevance of prior knowledge for successful transfer activities (D'Este et al., 2019; Llopis et al., 2018), we hypothesize for the transfer opportunity recognition that:

Hypothesis 1a: *The scientist's stock of academic knowledge increases the likelihood of recognizing a transfer opportunity.*

Similar to prior academic knowledge, prior non-academic knowledge, especially economic knowledge, can influence a scientist's transfer opportunity recognition. Shane (2000) points out the importance of prior knowledge about markets, how to serve them, and prior knowledge of customer problems to recognize opportunities. Building on this argument, related empirical findings show that experience outside academia decreases scientists' perception of Mertonian-related barriers to activities with industrial involvement (Merton, 1973; Tartari et al., 2012). Therefore, this reduction of perceived barriers might increase the willingness of scientists to keep their eyes open for transfer opportunities. Furthermore, scientists who have prior commercial experience, e.g. acquired in non-academic employment, accumulate context-specific skills, idiosyncratic information and economic knowledge (Vohora et al., 2004). Such knowledge from experiences outside the usual field of work gives a combined advantage and thereby facilitates the recognition of opportunities (Salter et al., 2015). This allows scientists to use their previously acquired knowledge from other domains to identify potential transfer opportunities that have a benefit for those same other domains. Also, experience outside academia gives insights into practical challenges and needs for which solutions are welcome. Given the relevance of non-academic prior knowledge, especially acquired in non-academic employment, we hypothesize that:

Hypothesis 1b: *The scientist's work experience outside academia increases the likelihood of recognizing a transfer opportunity.*

Scientific quality

The academic knowledge scientists generate can be characterized by its quality, e.g. in terms of its scientific relevance or how the findings shift the knowledge frontier. Especially high-quality knowledge influences scientific discourse and impacts subsequent research. Also, higher quality knowledge shows a higher relevance for the recognition of transfer opportunities for industrial applications (Murray & Stern, 2007). However, for finalized transfer activities, the quality of knowledge a scientist possesses provides ambiguous results (Perkmann et al., 2021). While Ding and Choi (2011) find a positive relationship between research quality and engagement in transfer activities, Tartari et al. (2014) and Giuliani et al. (2010) find a negative but insignificant relationship. For the recognition of a transfer opportunity, however, the quality of the generated knowledge can be highly relevant. The inherent novelty of high-quality research bears potential for as yet unrecognized opportunities for the industry. For example, scientists who generate high-quality knowledge have a comparative advantage in achieving breakthroughs that are of great importance to industry (Zucker et al., 1998). Especially, the recombination of existing and new knowledge increases novelty and usefulness (Xiao et al., 2022). Following this argument, Veugelers and Wang (2019) find a link between high-quality publications and technological impact. In related research, D'Este et al. (2012b) show that individual scientific quality, measured by the average number of citations to papers, significantly facilitates the discovery of IPR. Given the high relevance of the quality of knowledge a scientist posses, we hypothesize:

Hypothesis 2: *The quality of the scientist's research increases the likelihood to recognize a transfer opportunity.*

Relations to industrial actors

The recognition of a transfer opportunity can also be influenced by various interactions with industrial actors, a phenomenon frequently associated with relational capital (see, e.g. Bozeman & Corley, 2004; Davidsson & Honig, 2003; Dietz & Bozeman, 2005; Mosey & Wright, 2007; Wu et al., 2015). The access to sources for complementary knowledge acquisition can be achieved by relational assets and knowledge exchange and, thus, increase the potential for knowledge recombination (Andries et al., 2021; Ardichvili et al., 2003; Bhagavatula et al., 2010; Ramos-Rodríguez et al., 2010; Shane & Venkataraman, 2000). In particular, interaction with external market actors increases the recognition of opportunities as it creates awareness of current needs and problems of industrial actors (Gruber et al., 2013; Snihur et al., 2017). Landry et al. (2007) show that connections with industry are in general a good predictor for the successful implementation of technology transfer efforts. Having ties to the industry gives scientists commercial insights, leads to an envisioning of industrial applications and changes their perspective to an industrial one, enabling them to be boundary-spanning scientists (Dolmans et al., 2022). Furthermore, they can draw on their relationships to discuss their research results, or they are approached for solutions in the industry or gain inspiration for ideas on what can be done with their knowledge (Fritsch & Krabel, 2012; Nicolaou & Birley, 2003). Given the high relevance of interaction with industry in understanding the relevance of its own research for industry application, we hypothesize:

Hypothesis 3: *The scientist's relations to industrial actors increases the likelihood of recognizing a transfer opportunity.*

2.3 Choice of transfer channel

Since in the initiation phase of the KTT process the opportunity recognition coincides with the choice of a transfer channel, we argue that different factors can influence this choice. Given the three most frequent and economically relevant transfer channels S-I Collaboration, IPR and spin-off creation, we, first, consider scientists' research orientation toward basic and applied research as potential factors. Second, we argue that scientists' willingness to take risks influences the transfer channel choice due to a distinct risk associated with the transfer channels. Third, we consider the social context of the scientists through departmental role models they are exposed to as relevant for choosing a transfer channel.

Research orientation

Scientists' research orientation, i.e. the kind of research they are conducting, can be separated into basic research and applied research (Stokes, 1997). Basic research is defined as the fundamental advancement of scientific knowledge, such as the discovery of new relationships, materials, chemicals or any other fundamental discovery that shifts the scientific frontier. Basic research generates knowledge that is fundamental and considered to be temporally distant from and less certainly lead to commercial application. The economic value of basic research is difficult to forecast, making its economic payoff uncertain and in the case of foreseen economic relevance, often taking many years to unfold (Bartunek & Rynes, 2014; Dasgupta & David, 1994). Applied research, in contrast, discovers new scientific knowledge with specific practical or commercial objectives (Bartunek & Rynes, 2014; Godin, 2006). It is considered rather short- and mid-term oriented to time-to-capitalization. In a simplified transfer process of successive phases, it is closer to commercialization than basic research (Aghion et al., 2008). Therefore, applied research is closer to offering solutions to potential market needs with practical purposes and often addresses existing or potential market demands (Aghion et al., 2008; Bartunek & Rynes, 2014). Furthermore, applied research draws on user inspiration based on existing knowledge, which sometimes is even combined with existing technology to improve future technology (Stokes, 1997).

Given the differences in the nature of the two orientations toward research, the recognition of opportunities results in differences in the choice of the respective channels. Results from basic research can be of importance to industry. However, due to its fundamental nature, the discovery might require further application-oriented research to fulfill an economic purpose (David et al., 1992). This kind of research often cannot be pursued by the scientist alone due to a lack of financial resources, equipment or skills and knowledge (Ankrah et al., 2013). Therefore, upon the recognition of the transfer opportunity, the involvement of industrial partners becomes paramount for its realization. In such a S-I collaboration, corporate partners not only fill the resource gaps but can also set the direction of potential applications (Ankrah & AL-Tabbaa, 2015). If, however, the scientist has the required complementary assets and skills or can acquire them over time, the realization of the transfer opportunity can be done directly via a spin-off. Through this channel, the research results can be directly translated to customers via products or services by the scientist (Pirnay et al., 2003; Rappert et al., 1999). Based on this consideration, we propose that basic knowledge is relevant for the S-I collaboration and spin-off channel:

Hypothesis 4a: *The higher a scientist's extent of basic research orientation, the higher the likelihood to choose the S-I collaboration channel.*

Hypothesis 4b: *The higher a scientist's extent of basic research orientation, the higher the likelihood to choose the spin-off channel.*

Scientists who have a focus on applied research generate results that are closer to application and therefore commercialization (Leitner et al., 2021). The overall aim of generating knowledge that is close to application makes them aware of potential ways to commercialize it, especially via spin-off creation (Hossinger et al., 2021). The idea to bring its own research to the market and having entrepreneurial aspirations can influence the choice of the spin-off channel. However, the development of new products or services might require some adaptation and exploitation of existing knowledge (Vohora et al., 2004). Additionally, if such entrepreneurial aspirations are not present in the scientist (yet), intermediaries, such as technology transfer offices or venture capitalists, might approach scientists based on their research outcomes encouraging them to engage in spin-off creation (Duchek, 2013; Karnani, 2012). If the scientist does not want to actively engage in commercialization, a recognized opportunity can be legally protected and potentially commercialized as an IPR. It is a frequent outcome of applied research activities and some scientists might perceive IPRs as validation of their research and see them as potential quality signals to strengthen their reputation (Blind et al., 2018; Göktepe-Hulten & Mahagaonkar, 2010; Moutinho et al., 2007). Furthermore, in publicly funded applied research projects, IPR can be relevant to meet funding requirements. Besides their signaling value, scientists might perceive property rights as a risk-free additional source of income (Owen-Smith & Powell, 2001). Especially financially motivated scientists might be more interested in property rights promising considerable or fast returns. Based on these approaches to how applied research can be translated into commercial outcomes, we hypothesize the following:

Hypothesis 4c: *The higher a scientist's extent of applied research orientation, the higher the likelihood of choosing the spin-off channel.*

Hypothesis 4d: *The higher a scientist's extent of applied research orientation, the higher the likelihood of choosing the IPR channel.*

Risk willingness

Another influential factor can be a scientist's perception of risk and their willingness to engage in risky activities. Pursuing a recognized transfer opportunity can be associated with different degrees of risk, conditional to the transfer channel of choice. An individual's risk willingness is a personality characteristic describing an individual's disposition towards seemingly risky endeavors (van Gelderen et al., 2005), whereas risk defines the likelihood that an actual outcome will deviate from an expected outcome (Audretsch et al., 2002). In the following, we discuss the risk in terms of costs and benefits associated with different transfer channels and how the individual's risk willingness therefore influences the channel choice.

The choice of an S-I collaboration to pursue a recognized opportunity is usually associated with low or no opportunity costs, since the research is already an integral part of the scientist's activity (Arza, 2010). However, one could argue that there could be foregone opportunities to explore new research avenues with potentially higher impact. Nevertheless, the expected research output is subject to the same uncertainty as any other open-ended research activity (Stephan, 1996). Since such collaborations involve an industrial partner who acts as a sponsor, personal financial costs for the scientist are absent; however, there could be transaction costs in establishing the collaboration in the first place. Furthermore, there could be issues of appropriability of the generated results, since the industry partner could claim its exclusivity on the results and prohibit publication (AL-Tabbaa & Ankrah, 2016). Usually, contractual agreements can solve such problems ex-ante via non-disclosure agreements (Lee, 2000) or other arrangements. On the other hand, there can be several benefits from such activity, such as access to resources and knowledge (Lam, 2010). Also, the engagement may lead to new research ideas, scientific outcomes and repeated engagements (Cantner et al., 2022; de Fuentes & Dutrénit, 2012). Overall, S-I collaboration seems to have low financial and transactional costs which can be outweighed by the benefits of such engagement. We, therefore, do not assume that scientists require a high-risk willingness to choose S-I collaboration as a channel to realize their recognized transfer opportunity.

Disclosing a recognized opportunity for IPR protection can be associated with opportunity costs. The scientist can be constrained by being well advised to not publish their results before the IPR is filed to maintain the novelty of the claims (Florida, 1999; van Looy et al., 2004). Furthermore, a granted patent, for example, can be challenged and infringement claims be put forward. However, usually the institution as a patent applicant would be challenged and bear the legal risk. With respect to these potential opportunity costs, empirical evidence suggests that scientists do not perceive a reduction in their opportunities or a decline in their research activity (Tartari et al., 2012). Furthermore, there are no financial costs for scientists to file for IPR protection, since such costs are usually covered by the host institution which carries the entire financial risk (Czarnitzki et al., 2011). With respect to the benefits, the successful commercialization of an IPR can result in substantial financial rewards for the individual. Furthermore, IPRs are considered a signaling instrument for scientific success, prerequisites in some funding applications or starting points for further commercialization (Blind et al., 2018; Göktepe-Hulten & Mahagaonkar, 2010). Overall, the institutional setup with respect to IPRs and the empirical evidence suggests that the costs of choosing this channel are very low, but the benefits can be substantial. Therefore, the risk willingness should not have an influence on the choice of the IPR channel.

Founding a spin-off as the chosen transfer channel for a recognized opportunity bears high opportunity costs as well as personal financial costs. Haeussler and Colyvas (2011) explicate that the creation of an academic spin-off is the most binding and riskiest transfer channel for scientists. With respect to the opportunity costs, the process of founding a company is an extensively time-consuming endeavor that binds substantial resources that cannot be devoted to research (Lacetera, 2009). This is often perceived as a major barrier in the process of spin-off creation (Hossinger et al., 2020; Neves & Franco, 2018). Furthermore, since the founding of a spin-off entails leaving the academic system, it can bear substantial financial risk because it often requires personal financial investment to found and run the firm and also foregone salary if the scientist reduces or quits the academic activity. However, some scientists consider the creation of a spin-off as a second-best alternative to an academic career if they cannot get tenure (Civera et al., 2020; Horta et al., 2016; Vismara & Meoli, 2016). Nevertheless, if the scientist leaves the academic position to work full time in the spin-off, financial risks can become dire (Åstebro et al., 2013; Forlani & Mullins, 2000). With respect to the benefits, academic spin-offs can be highly successful and provide large financial returns and reputation, as some leading examples show. However, the distribution of success is highly skewed and the survival rate of academic spin-offs is quite low (Criaco et al., 2014; Gurdon & Samsom, 2010; Rodeiro-Pazos et al., 2021; Rothaermel & Thursby, 2005; Wennberg et al., 2011). Overall, choosing to commercialize the recognized transfer opportunity via a spin-off can entail a high risk for the scientists. Consequently, scientists who choose this channel must possess a high risk willingness. Therefore, we hypothesize that:

Hypothesis 5: *The higher the scientist's risk willingness, the higher the likelihood of choosing spin-off creation as a transfer channel.*

Role models

Finally, the social context in which the scientist recognizes the transfer opportunity might affect the scientist's choice of a transfer channel. Generally, a scientist's relationship with intra-organizational peers has a significant effect on their behavior, e.g. mimicking the behavior of peers (Bercovitz & Feldman, 2008; Broström, 2019). For the case of KTT activities, the engagement of peers in such endeavors creates awareness of such activities and potentially influences an individual's orientation towards such engagement (Aschhoff & Grimpe, 2014; Ding & Choi, 2011; Greven et al., 2020; Tartari et al., 2014). Marquis and Tilcsik (2013) argues that *alignment* is the underlying mechanism that leads to the "imprinting" of characteristics and behaviors of individuals that reflect the specifics of the environment in which they operate. This mechanism is especially prominent in role models who can have a formative impact on scientists' alignment with peers' behavior and, thus, adaptation to their social context. Gibson (2004) characterizes role models as encompassing individuals' cognitive construction based on attributes of people in social roles observed in the environment. Accordingly, role models are those who are perceived by the observer as having similar characteristics and whose behavior is considered worth striving for. The cognitive process of role modeling is an observation and adaptation of the attributes of multiple role models. Thereby, attributes that are considered negative can also be rejected.

In the context of KTT, Huyghe and Knockaert (2015) find evidence for a positive relationship between channel-specific role models, i.e. observable successful peers in a particular transfer channel, and scientists' intention to engage with the respective channel. For the particular channels, Scherer et al. (1989), for instance, find that role models are decisive to follow an entrepreneurial career path, while Bercovitz and Feldman (2008) provide such evidence for invention disclosure activities. In a similar vein, Tartari et al. (2014) find that departmental peers affect scientists' collaborative engagement with industrial partners. For each channel, role models can lead by example and increase scientists' awareness of a specific transfer channel. In this sense, role models can be important factors in forming activity and even career preferences (Gibson, 2004; Scherer et al., 1989). Based on these arguments, we hypothesize a positive relationship between the presence of role models for a specific transfer channel and the choice of this transfer channel to pursue the recognized opportunity. The corresponding hypothesis states:

Hypothesis 6: *The extent of departmental role models for (a) S-I Collaboration, (b) protection of IPR or (c) spin-off creation is positively related to scientists' choice of the respective transfer channel.*

3 Data and Method

3.1 Data

To investigate scientists' transfer initiation, we conducted a novel online survey of academic staff at both universities and research institutes in the German Federal State of Thuringia. Thuringia captures the variety in the German research landscape well, as there are four universities and about 25 research institutes. More precisely, one of these universities is a technical university and one is affiliated with a university hospital. Furthermore, the university landscape is enriched with seven universities of applied sciences, including one music college. The research institutes cover the whole range from basic science-oriented institutes to applied science-oriented institutes (e.g. Max Planck Institute, Fraunhofer Society, etc.). This heterogeneity of organizations guarantees coverage of a wide range of disciplines and organizational research orientations (for an overview, see Table S3).

We collected publicly available contact information and characteristics of the scientists from their organizations' web presence. Overall, we identified 7,785 scientists to whom we sent the invitation for our web-based survey in December 2019 and January 2020. We received 1,409 responses (18.1% response rate) of which we excluded 265 observations due to incomplete answers and run our analysis with a working sample of 1,149 observations. The differences between this working sample of respondents and the initial population are marginal, and we consider a non-response bias unlikely.[3] Comparing the working sample with the overall population of scientists at universities in Germany (Statistisches Bundesamt, 2020), we can claim representativeness of our sample in terms of academic rank and gender (Table S2).

Our online survey consists of a set of questions on the scientist's transfer activities in the three channels S-I collaboration, the protection of IPR and the creation of an academic spin-off. For each channel, we included a question regarding the transfer initiation during the last five years. We developed the items to capture the potential of KTT at the very beginning of the transfer process. This is opposed to many studies looking at the end of KTT processes, i.e. KTT outputs in terms of realized transfer such as created spin-offs or licensed IPRs. To ensure the reliability of these items, we discussed them with colleagues specialized in the field and practitioners from technology transfer offices. Subsequently, we conducted a pre-test of our survey in a comparable German state with a random sample of scientists, as suggested by Sue and Ritter (2007). Furthermore, in our survey, we collected information on scientists' characteristics regarding their socio-demographic situation, research activity and personality.

In addition to the survey data, we gathered data on the respondents' publication records from Web of Science (WoS) and Scopus.[4] For the scientists' publications, we collected the respective source normalized impact factor (SNIP), retrieved from the journal record of Scopus.

3.2 Empirical strategy

In our empirical approach, we have to account for the whole initiation process, the antecedents of scientists' recognition of a transfer opportunity and the simultaneous choice of the transfer channel. In this setting, however, a transfer channel is chosen only by those scientists who have transfer opportunity recognition (TOR). This implies that the choice of the transfer channel

[3] We compared the characteristics position, gender, organizational focus and academic discipline between the overall population and the working sample (Armstrong & Overton, 1977) in Table S1. There are some statistically significant differences concerning the disciplines. There is especially an under-representation of scientists from medicine in our respondents. We believe that our initial data collection included many medical doctors with an affiliation with the university hospital but who are not involved in research anymore.

[4] Our primary source for publication data is WoS. If there was no publication record in WoS for a respondent, we went to Scopus which has a larger coverage for some disciplines esp. for social sciences and humanities (Martín-Martín et al., 2021). If, again, there were no publications in Scopus listed, we assumed zero publications, which is especially plausible for PhD researchers at the beginning of their academic careers. In doing so, we might underestimate the influence of our respondents' publications.

is of non-random character and requires an account of the respective selection process in our empirical approach. If we would ignore the selection and estimate the channel's choice by treating the transfer initiators' choice of the transfer channel as a random sample, we would generate inconsistent estimates (Heckman, 1979). Furthermore, including the recognition of a transfer opportunity as an exogenous variable when estimating the channel choice would not take into account the endogeneity between the choice of the transfer channel and the recognition of a transfer opportunity. Therefore, a proper solution to this is to include the scientists' self-selection in the choice of the transfer channel in our econometric model. Consequently, we estimate a selection equation which corrects for potential selection bias in the opportunity recognition, while the choice of the three transfer channels is the outcome equations. Given that the three transfer channels are non-exclusive, scientists can recognize multiple transfer opportunities for which they can choose different transfer channels. To account for the possibility of multiple channel choices by a scientist, we allow the error terms of the outcome equations to be correlated.

We use a multivariate probit model with a correction for self-selection and the possibility of choosing multiple transfer channels. To account for the meaningful correlations between the error terms of the different relationships between the dependent variables, we rely on seemingly unrelated regressions (SUR) (Roodman, 2011). In this setting, the SUR estimates will be more efficient than those derived from single-equation regressions because SUR take into account those correlations. SUR account for simultaneous relationships between the dependent variables by allowing the error terms of each equation in the model to correlate and let them share a multivariate normal distribution. This enables us to control for our selection bias and to allow for scientists' multiple channel choices. However, when correcting for a self-selection bias, it is necessary to include an exclusion restriction. This requires identifying at least one variable in the selection equation that affects the probability of recognizing a transfer opportunity but does not influence the outcome, i.e. the choice of the transfer channel. We explain our chosen variables for the exclusion restriction in more detail below in section 3.3.

Our regression model is separated into the selection equation and three outcome equations capturing the three considered transfer channels. Equation 1 depicts the selection equation where the probability of each scientist i to have a transfer opportunity recognition (TOR_i) or not is explained by the vector PK_i, capturing academic and non-academic prior knowledge, SQ_i for scientific quality and RI_i for relations to industrial actors. $Excl_i$ is a vector of two variables for the exclusion restriction, X_i is a vector of the control variables and $\varepsilon_{i,S}$ is the error term for the selection equation.

$$Pr(TOR_i = 1) = \beta_0 + PK_i\beta_1 + SQ_i\beta_2 + RI_i\beta_3 + Excl_i\beta_4 + X_i\beta_5 + \varepsilon_{i,S} \tag{1}$$

The outcome equation 2 for the scientist i's choice among the three transfer channels is the probability to choose channel C defined by $Pr(C_i = 1)$ with $C = \{$S-I collaboration, IPR, spin-off$\}$. Our explanatory variables for i' channel choice are the research orientation (RO_i), a vector containing applied and basic research, the risk willingness ($Risk_i$) and channel-specific role models ($Role_{i,C}$). $\varepsilon_{i,C}$ are the channel-specific error terms.

$$Pr(C_i = 1) = \beta_0 + RO_i\beta_2 + Risk_i\beta_3 + Role_{i,C}\beta_{4,C} + X_i\beta_5 + \varepsilon_{i,C} \tag{2}$$

Due to the correlation among the dependent variables, the error terms are potentially correlated, too. The error terms follow a multivariate normal distribution with a mean of zero and variance-covariance matrix with off-diagonal elements $\rho_{i,j} = \rho_{j,i}$. They capture an unknown variable that connects the outcomes. To simplify denotation, we introduce: $TOR = 1$, $C_{S-I\,Collaboration} = 2$, $C_{IPR} = 3$, $C_{Spin-off} = 4$.

$$\left(\begin{array}{c|c} \varepsilon_1 & \\ \varepsilon_2 & \mathrm{X} \\ \varepsilon_3 & \\ \varepsilon_4 & \end{array} \right) \sim N \left[\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho_{1,2} & \rho_{1,3} & \rho_{1,4} \\ \rho_{2,1} & 1 & \rho_{2,3} & \rho_{2,4} \\ \rho_{3,1} & \rho_{3,2} & 1 & \rho_{3,4} \\ \rho_{4,1} & \rho_{4,2} & \rho_{4,3} & 1 \end{pmatrix} \right] \tag{3}$$

3.3 Variables

Dependent variables

To understand the transfer initiation, we need one dependent variable for the recognition of a transfer opportunity (selection) and three dependent variables for the different channels a scientist can choose from (outcome). Since a transfer opportunity recognition requires that a channel is chosen, we do not need to ask the scientists in our survey if they have recognition of an opportunity, in general, but can directly ask them about their chosen channel. We use the information on the channel choice to construct the *transfer opportunity recognition (TOR)*. For each of the different channels, we asked the scientists whether they identified or developed an idea for the respective channel within the last five years. In particular, for the transfer channel *S-I Collaboration* we asked respondents how many times in the last five years they had been involved in the "development of an idea for a cooperation with company participation, i.e. identification of a research question or problem for which cooperation between universities and companies could be helpful". For the IPR channel respondents should indicate how often they had an "identification of an idea or invention that can be attributed to potential industrial exploitation or can be legally protected". For the *Spin-off* channel we asked how often the respondent was involved in the "development of an idea to found a firm, e.g. discussion of the idea with others, assessment of the economic potential or application of creative techniques". We recoded the responses of each of the three transfer channels into binary variables, since we are not interested in the frequency of recognition but only if a recognition happened at all. We end up with the three outcome variables *S-I Collaboration (=1)*, *IPR (=1)* and *Spin-off (=1)*. We use the three outcome variables to construct our transfer opportunity recognition which is equal to 1 for every scientist who has a transfer opportunity in any of the three channels (*TOR (=1)*).

Explanatory variables for the transfer opportunity recognition

To understand what influences the probability of a transfer opportunity recognition, we use two variables to capture scientists' prior academic and non-academic knowledge. First, we operationalize the stock of academic knowledge by the scientists' overall *Number of publications*. The scientist's publication output is a frequently used measure to account for the scientific performance and the accumulated knowledge (Perkmann et al., 2021). We log-transform the variable to account for its right-skewed distribution. Second, our proxy for scientists' non-academic prior knowledge is the scientist's *Work experience outside academia*. It is obtained from a survey item capturing the years a scientist has worked outside academia. Previous research shows that scientists who accumulate work experience outside academia are more likely to engage in commercial activities and to better adapt to their requirements (Gulbrandsen & Thune, 2017).

Furthermore, we account for the scientific quality of the scientists' research output. We argue that scientists' research output must also have a certain quality to draw promising ideas for KTT from it. We use the *Average impact factor*, representing the average of the publications' source normalized impact factor (SNIP) as provided in the journal record of Scopus. SNIP accounts for differences across disciplines when calculating the impact of a publication.

To capture scientists' relations to industrial actors, we again draw on the scientists' publication record. We measure how frequently their research is co-published with industry partners. While co-publishing is an important relational asset for the implementation of transfer opportunities (D'Este et al., 2012b; Fritsch & Krabel, 2012; Krabel & Mueller, 2009), we argue that it is also relevant for the recognition of transfer opportunities. We calculate the fraction of papers with at least one co-author affiliated to industry over the total number of publications, which results in the *Share of publications with industry*.

Exclusion restriction

To account for the bias introduced in the channel choice due to the selection into having a transfer opportunity recognition, we need to include at least one variable that is correlated with the recognition of the transfer opportunity but is independent of the channel choice (Wilde, 2000). We use two variables that fulfill this exclusion restriction. The first variable is the general *Organizational transfer orientation* which is, according to Jacobson et al. (2004), a proxy for the priority universities and research institutes given to transfer activities via policies and practices. Throughout the last decades, universities and research institutes have been required to act more "entrepreneurial" (Etzkowitz et al., 2000; Guerrero & Urbano, 2012), which affects their strategic alignment towards third mission activities, as well as their research commercialization culture (Giuri et al., 2019). This orientation towards transfer into industrial application reduces the boundaries between academia and industry by institutionalizing commercial norms and logics that coexist with academic ones. This increases the likelihood that scientists see opportunities to transfer their research (Colyvas, 2007; Murray, 2010; Perkmann et al., 2019). Consequently, research results regarding this relationship show a strong association between universities' orientation towards third mission activities and its impact on KTT activities (Balasubramanian et al., 2020; Kalar & Antoncic, 2015; Todorovic et al., 2011).

However, this established transfer culture and the respective environment that supports such activity does not discriminate between the different channels. Research organizations aim in their third mission activities and respective strategies to strengthen these activities in general (Horner et al., 2019). The respective infrastructure, such as TTOs, are usually one-stop shops for scientists who want to bring their recognized ideas into industry application and provide tailor-made support for the idea, which covers all the different transfer channels (Zhou & Tang, 2020). Furthermore, most evaluations of transfer activities assess the whole range of activities so that the organizations do not focus on particular channels but instead cover the whole range. Overall, the *Organizational transfer orientation* should therefore influence scientists to recognize transfer opportunities but should not influence the subsequent choice of the transfer channel. We measure the *Organizational transfer orientation* via the share of scientists who recognized at least one transfer opportunity affiliated with the same organization as the focal scientist.

The second exclusion restriction accounts for whether the scientist's position is based on *Internal funding* or not. We exploit the peculiarity of the German science system that a scientist's position can be financed via money from the budget of the organization or via third-party funding, such as grants or scholarships. The latter is, however, short term and prolongation of a position is highly uncertain. Scientists funded with internal money, however, either hold a permanent position or an extension of the contract is more likely.[5] We argue that this kind of funding influences the likelihood to recognize transfer opportunities. First, internal funding, especially a permanent position, ties the scientist more strongly to their organization. This increases their embeddedness in the academic system and strengthens a role characterized by a focus on research and teaching (Dasgupta & David, 1994; Merton, 1973) and reduces the need to search for alternatives. Landry et al. (2010), for instance, show that if the scientist's position is funded internally, KTT activities are reduced. Scientists, however, who are financed via external funding know that a follow-on position is highly uncertain and that they need to search for potential alternatives or ways to extend their position. Related empirical results show that industrial funding increases scientists' interaction with industry (Boardman & Ponomariov, 2009; Gulbrandsen & Smeby, 2005; Landry et al., 2010) indicating that such third-party funding is helpful to establish further interaction. Second, the *Internal funding* is typically associated with significant teaching duties, while third-party funding does not require teaching. Since a high teaching load can disincentivize scientists' appeal for transfer activities (Landry et al., 2007), scientists with a position that is internally funded should be less likely to recognize a transfer opportunity.

While the funding of a position should have an influence on the likelihood to recognize a transfer opportunity, it should not influence the transfer channel choice. The different channels can all provide an opportunity for externally funded scientists to result in the potential prolongation of contracts or alternative employment. But also internally funded scientists can benefit from the different channels. Industry collaboration can increase financial means to finance one's own position or to hire additional scientists (Ankrah et al., 2013). Patents can be counted as scientific output to gain reputation or to signal industry applicability (Blind et al., 2018; Göktepe-Hulten & Mahagaonkar, 2010; Moutinho et al., 2007). Academic entrepreneurship can be the sole employment or be done in parallel to an academic position (Civera et al., 2020; Horta et al., 2016; Vismara & Meoli, 2016). In this sense, the rewards that can be derived from the different channels do not depend on the initial financial background of the individual scientists. For our econometric approach, to indicate whether a scientist's position is based on *Internal funding*, we asked a respective question in our survey (see Table A1) and created a binary variable based on the response.

[5] The German law governing the non-permanent positions at research organizations (Wissenschaftszeitvertragsgesetz) grants up to six years of employment for pre-doc scientists and six years for post-doc scientists (as well as several exceptions, such as extra years for childcare).

Explanatory variables for channel choice

To test our hypotheses with respect to channel choice, we rely on four variables that we expect to influence the scientists' choice. We include the two variables *Basic research* and *Applied research* to capture scientists' research orientation within the last five years. Following Amara et al. (2019), respondents were asked to indicate the extent to which they consider their research as basic or applied. *Basic research* is characterized by contributions to fundamental understanding whereas *Applied research* is characterized by the consideration of use. Both variables were assessed on a 4-point Likert scale, ranging from "not at all" to "a lot".

To measure the scientist's willingness to take risks and test its influence on the channel choice, we asked the participants about their *Risk willingness* according to SOEP-IS Group (2014, p. 36) with the following question: "How do you see yourself? Are you generally a person who is fully prepared to take risks or are you trying to avoid risks?" Respondents were asked to assess their *Risk willingness* on an 11-point Likert scale ranging from "risk averse" to "fully prepared to take risks". The 11-point Likert scale proves to be a valid and reliable survey method to capture the willingness to take risks (Beierlein et al., 2014).

To capture the relevance of channel-specific *Role models*, we create three different variables tailored to the respective transfer channel. In our understanding, role models are scientists who have successfully exploited an opportunity. This means that they have successfully realized a transfer activity in the respective channel, which is in line with Huyghe and Knockaert (2015). Furthermore, we argue that role models must be observable to have an impact. Therefore, we refer to role models as the scientist's colleagues at the same department or research institute who successfully realized a transfer opportunity at least once in a specific channel. For instance, a colleague who founds a firm would be considered a spin-off role model. Since all survey participants were asked to state their realized transfer activities in the last 5 years, we can utilize this information to create such role models. For S-I collaboration, we asked for the "Realisation or participation in a research cooperation with company participation", for IPR whether "Selling or licensing of an idea or invention, e.g. selling a patent to a company" took place and for spin-off if the scientists "Completed foundation of a firm, i.e. the launch of business activities". Each variable for channel-specific *Role models* is created as the share of scientists at a university department or research institute with successfully realized transfer in all scientists at that organizational unit.

Control variables

We control for several factors that can influence the recognition of a transfer opportunity in the selection equation and the channel choice in the outcome equations. First, to control for differences in academic rank, we create a dummy variable distinguishing between *Professor (=1)* and other types of researchers, e.g. post-docs, Phd students, ... (Perkmann et al., 2021).[6] Second, we control for scientists' gender and distinguish between *Female (=1)* and others. This is motivated by the strong gender gap identified in the KTT-related literature (see, e.g. Abreu & Grinevich, 2017; Tartari & Salter, 2015). Third, we control for differences between *Disciplines* to account for differences in their transfer propensity (see, e.g. Abreu & Grinevich, 2013; Perk-

[6]We treat junior professors at universities as well as directors or heads of departments in research institutes equal to full professors.

mann et al., 2011). We distinguish between seven *Disciplines*: *Engineering*, *Humanities*, *Life Sciences*, *Medicine*, *Physics*, *Chemistry*, *Social Sciences* and *Computer Science and Mathematics*. Lastly, we control for organizational heterogeneity in the type of generated knowledge that might influence scientists' cognitive proximity to research commercialization (e.g. Bercovitz & Feldman, 2008). We create a categorical variable to account for the *Organizational focus*. It distinguishes the research focus of the scientists' organization into three groups: *Basic*, *Between basic and applied* and *Applied*. For the categorization, we rely on the German Ministry for Science and Education (BMBF, 2014).[7]

4 Results

4.1 Descriptive results

Descriptive statistics are provided in Table 1 and distinguished for variables of the selection equation and the outcome equations. The statistics give first indications of the frequencies of opportunity recognition and the characteristics of the scientists who have it. The descriptive results show that 44% (504 out of 1,149) of the scientists have a transfer opportunity recognition. Among the scientists who recognized transfer opportunities, we observe that they most frequently chose S-I collaboration with 82% (412 out of 504). Considerably fewer pursue their recognized transfer opportunity in the IPR and the spin-off channel with 47% (235 out of 504) and 49% (249 out of 504), respectively. Since scientists can recognize several transfer opportunities for which they can consider different transfer channels, we represent the combinations of channels in Figure 1. In the Venn diagram, overlapping circles indicate scientists' pursuit of transfer opportunities through multiple channels. For instance, we can see that 119 of the 504 scientists (23.6%) recognized in all three channels at least one transfer opportunity. Furthermore, 79 (15.7%) of the scientists chose the combination of the channels S-I collaboration and IPR, 15 (2.98%) combined IPR and spin-off and 60 (11.9%) decided to pursue their transfer opportunities through the channels spin-off and S-I collaboration. Overall, more than half of the scientists (54.18%) recognized transfer opportunities in more than one channel.

Among the explanatory variables for the transfer opportunity recognition, we observe that the average *Number of publications* is comparatively low, presumably because of the high share of scholars who have not reached professorship. In line with that, the *Average impact factor* is low. *Work experience outside academia* seems to be the exception in our sample with the low mean and larger variance. Also, there is a low average *Share of publications with industry*. For the variables explaining the channel choice, we observe that on average, more scientists consider their work as *Applied research* than as *Basic research*. The scientists' *Risk willingness* centers around the mean of the 11-point Likert scale. Among the role models, *Role models: S-I Collaboration* are very frequent, while the other two role models are rather scarce.

With respect to the control variables, the share of *Professors* is around one fifth and there is a slight increase of their frequency in the scientists who recognized a transfer opportunity. By contrast, the share of *Female* scientists drops from 37% in the overall sample to 31% who

[7] Research institutes of the Leibniz Association, the Max Planck Society and similar are allocated to basic research. Universities are located between basic and applied research and universities of applied sciences as well as institutes such as the ones from the Fraunhofer Society and similar are allocated to applied research (see Table S3).

recognized a transfer opportunity. Among the disciplines, we observe a quite equal distribution of disciplines from 10% to 20% in the overall sample but a more heterogeneous distribution for the scientists who recognized an opportunity. However, the changes are not surprising: increases for *Engineering*, *Physics and Chemistry* and *Computer Science and Mathematics* and decreases especially for *Humanities* and *Social Sciences*. The organizational focus indicates that the majority of respondents works in universities. There are some small changes from the overall sample to the scientists who recognized an opportunity, indicating that scientists in application-oriented organizations have a higher likelihood to recognize opportunities. If we turn to the correlation between the explanatory variables (Tables S4 and S5), there are no substantial correlations in the data.

Table 1: Descriptive statistics.

	Selection TOR (=1)				Outcomes S-I-C (=1), IPR (=1), Spin-Off (=1)			
	mean	sd	min	max	mean	sd	min	max
Dependent variables								
Transfer opportunity recognition (=1)	0.44	0.50	0	1				
S-I Collaboration (=1)					0.82	0.39	0	1
IPR (=1)					0.47	0.50	0	1
Spin-off (=1)					0.49	0.50	0	1
Antecedents of transfer opportunity recognition								
Number of publications (log)	1.85	1.56	0	6.30				
Work experience outside academia	1.36	1.45	0	4				
Average impact factor	0.91	0.79	0	4.80				
Share of publications with industry	0.03	0.12	0	1				
Exclusion restriction								
Organizational transfer orientation	0.45	0.18	0	1				
Internal funding (=1)	0.49	0.50	0	1				
Variables for channel choice								
Basic research					2.65	0.71	1	4
Applied research					3.08	0.75	1	4
Risk willingness					6.75	2.07	1	11
Role models: S-I Collaboration					0.46	0.25	0	1
Role models: IPR					0.10	0.14	0	1
Role models: Spin-off					0.08	0.09	0	1
Control variables								
Professor (=1)	0.18	0.39	0	1	0.22	0.41	0	1
Female (=1)	0.37	0.48	0	1	0.31	0.46	0	1
Discipline: Computer Science and Mathematics	0.11	0.31	0	1	0.14	0.35	0	1
Discipline: Engineering	0.16	0.37	0	1	0.24	0.43	0	1
Discipline: Humanities	0.10	0.29	0	1	0.05	0.22	0	1
Discipline: Life Sciences	0.15	0.36	0	1	0.12	0.33	0	1
Discipline: Medicine	0.10	0.30	0	1	0.09	0.28	0	1
Discipline: Physics and Chemistry	0.20	0.40	0	1	0.22	0.41	0	1
Discipline: Social Sciences	0.19	0.39	0	1	0.13	0.34	0	1
Organizational focus: Basic	0.15	0.36	0	1	0.13	0.34	0	1
Organizational focus: Between basic and applied	0.64	0.48	0	1	0.58	0.49	0	1
Organizational focus: Applied	0.20	0.40	0	1	0.29	0.45	0	1
N	1,149				504			

4.2 Regression results

The results of our empirical analysis are presented in Table 2. The first column shows the estimates of our selection equation which is relevant to test hypotheses 1a, 1b, 2 and 3. The remaining columns represent the three transfer channels scientists can choose for the pursuit of their recognized transfer opportunity. Since scientists can choose multiple channels, we estimate a multivariate probit model which provides correlation coefficients of the error terms that we

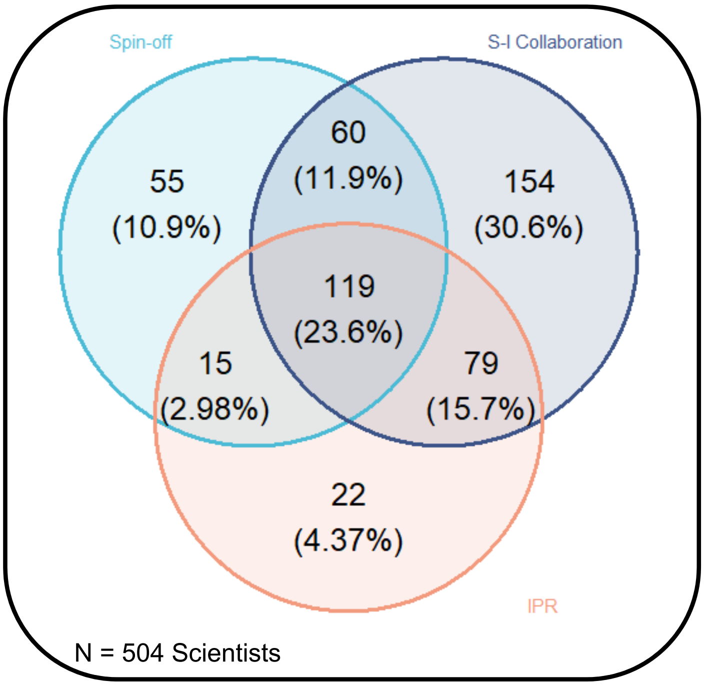

Figure 1: Venn diagram of the scientists' transfer channels choice (N=504).

present in the lower part of the table. The error terms show for the prevalence of selection mechanisms in column (1) that these occur mainly for the *S-I Collaboration* and *IPR* channel. Therefore, accounting for selection is essential to obtain unbiased estimates. Furthermore, there is a significant negative relationship between the choice of *S-I Collaboration* and *Spin-off*, indicating an opposing relationship between those two channels.

Our regression results regarding hypotheses 1a and 1b in the selection equation in column (1) show a positive and significant correlation between the *Number of publications* and the probability to recognize a transfer opportunity *(TOR (=1))*. The same holds for the *Work experience outside academia*. The results support hypotheses 1a and 1b stating a positive influence of prior academic and prior non-academic knowledge on transfer opportunity recognition. The coefficient for the *Average impact factor*, our proxy for scientific quality, is negative and significant. This goes against our hypothesis 2 that proposed a positive relationship with the TOR. The *Share of publications with industry* has no significant influence on the TOR and therefore does not support hypothesis 3 on the relevance of relations to industrial actors. Besides the core variables for our hypotheses, the exclusion restriction, *Organizational transfer orientation* and *Internal funding*, both show the expected and necessary correlation with *TOR (=1)*.[8] Furthermore, among the control variables, those in the disciplines *Humanities* and *Social Sciences* have a significantly lower probability to recognize a transfer opportunity compared to the baseline category *Computer Science and Mathematics*.

The results for the factors that influence the choice of a transfer channel can be obtained from columns 2-4 for the three channels. With respect to *Basic research*, the coefficient is only positive and significant for the choice of the spin-off channel and insignificant for the others.

[8]We tested whether our two variables for the exclusion restriction are valid by running our model with these variables included in the outcome equations, too. They turned out to be not significant for any of the outcomes, indicating the exclusion restriction served its purpose (see Table S6 in the Online Appendix).

Table 2: Results of Seemingly Unrelated Regressions (SUR) with Selection.

	Selection	Outcomes		
	(1) TOR (=1)	(2) S-I Collaboration (=1)	(3) IPR (=1)	(4) Spin-off (=1)
Antecedents of transfer opportunity recognition				
Number of publications	0.234***			
	(0.036)			
Work experience outside academia	0.079**			
	(0.037)			
Average impact factor	-0.215***			
	(0.075)			
Share of publications with industry	0.417			
	(0.373)			
Exclusion restrictions				
Organizational transfer orientation	2.068***			
	(0.321)			
Internal funding (=1)	-0.241***			
	(0.091)			
Factors of channel choice				
Basic research		-0.094	0.089	0.216**
		(0.086)	(0.083)	(0.083)
Applied research		0.133	0.262***	0.057
		(0.089)	(0.079)	(0.085)
Risk willingness		-0.001	-0.011	0.098***
		(0.030)	(0.027)	(0.029)
Role models: S-I Collaboration		-0.599*		
		(0.356)		
Role models: IPR			1.497***	
			(0.574)	
Role models: Spin-off				1.328**
				(0.616)
Control variables				
Professor (=1)	0.140	0.270	0.037	0.018
	(0.123)	(0.167)	(0.151)	(0.151)
Female (=1)	-0.018	0.285**	-0.213	-0.326**
	(0.086)	(0.140)	(0.132)	(0.130)
Discipline: Engineering	-0.015	0.174	-0.006	-0.044
	(0.159)	(0.244)	(0.193)	(0.203)
Discipline: Humanities	-0.392**	-0.869**	0.386	1.022**
	(0.199)	(0.400)	(0.332)	(0.419)
Discipline: Life Sciences	-0.259	-0.264	0.404	0.380
	(0.175)	(0.284)	(0.248)	(0.282)
Discipline: Medicine	-0.173	-0.344	0.399	0.117
	(0.188)	(0.287)	(0.244)	(0.270)
Discipline: Physics and Chemistry	-0.076	-0.122	0.413**	0.183
	(0.162)	(0.225)	(0.196)	(0.209)
Discipline: Social Sciences	-0.309*	-0.184	0.139	0.085
	(0.161)	(0.276)	(0.250)	(0.277)
Organizational focus: Basic	-0.014	-0.184	-0.010	-0.381*
	(0.131)	(0.207)	(0.193)	(0.208)
Organizational focus: Applied	0.139	-0.040	-0.131	0.077
	(0.130)	(0.188)	(0.153)	(0.168)
Constant	-1.201***	1.468***	-0.927**	-1.710***
	(0.223)	(0.424)	(0.448)	(0.418)
	$\varepsilon_{Selection}$	$\varepsilon_{Collaboration}$	ε_{IPR}	$\varepsilon_{Spin-off}$
$\varepsilon_{Collaboration}$	-0.626***			
	(0.168)			
ε_{IPR}	-0.505**	0.198		
	(0.243)	(0.121)		
$\varepsilon_{Spin-off}$	0.212	-0.435***	0.151	
	(0.282)	(0.100)	(0.141)	
N		1,149		
Pseudo Log-Likelihood		-1520.9598		
Wald Chi^2		271.32		

Note: Robust standard errors in parentheses. Significance levels at *** p<0.01, ** p<0.05, * p<0.1.

We, therefore, find no support for hypothesis 4a but for 4b. For *Applied research*, a positive and significant coefficient for the IPR channel is obtained and insignificant ones obtained for the other two channels. Respectively, there is no support for hypothesis 4c but for 4d. Concerning the scientists' *Risk willingness*, there is a positive and significant coefficient for choosing the spin-off channel. This provides support in favor of hypothesis 5. For the channel-specific *Role models*, a negative and significant coefficient is obtained for the S-I collaboration channel, while for the other two channels, the coefficient is positive and significant. With these results, we find only partial support for our hypothesis 6. With respect to the control variables, some interesting relationships exist. *Female* scientists are more likely to choose the S-I collaboration channel but less likely to choose the spin-off channel. Furthermore, scientists from the *Humanities* are less likely to recognize opportunities for S-I Collaborations but more likely to see such opportunities for spin-offs compared to the reference category *Computer Science and Mathematics*. Scientists from *Physics and Chemistry* are more likely to choose the protection of IPR compared to the baseline. Scientists employed in organizations focusing predominantly on basic research have a lower probability to choose the Spin-off channel.

4.3 Robustness tests

We conduct three robustness tests to our main specification. First, we use an alternative estimation procedure to check whether the results are driven by the choice of multiple channels. Second, we perform a subsample analysis and exclude scientists from the Humanities and Social Sciences which can have substantially different transfer activities. Third, since the *Work experience outside academia* and the *Share of publications with industry* show very low values, we transform these continuous variables to dummy variables to check whether it is the instance or the magnitude that characterizes the underlying mechanisms. All results are presented in the Appendix.

First, we model the initiation of KTT separately for the three transfer channels by estimating a Heckprobit two-stage model for each channel. Each of the three models consists of a selection and an outcome. The transfer opportunity recognition always represents the selection, while the channel under consideration constitutes the outcome of the model. While the Heckprobit models do not account for the possibility of multiple outcomes, i.e. using more than one channel to follow up on a recognized opportunity, they do correct for selection bias. Also, they produce robust coefficients when focusing on a specific channel (Miranda & Rabe-Hesketh, 2006). Results are very similar to our main model estimated with the SUR method, regarding both antecedents of transfer opportunity recognition and the factors of channel choice (Table A2). This indicates that the selection of multiple channels does not influence the results.

Second, we re-estimate the SUR model excluding scientists from social sciences and the humanities (Table A3). The reason is to assess potential differences in industrial applicability of knowledge within the academic disciplines. Scientists in these disciplines are predominantly engaged in transfer activities through consultancy, contract research or training (Olmos-Peñuela et al., 2014) – transfer channels that are not considered in our more commercially oriented view of transfer and for which no transfer opportunity by the scientist is the initiating step. The results are very similar to our main model. The only essential difference is that the coefficient for *Role models* for the spin-off channel is not significant any longer.

Third, we convert the *Work experience outside academia* and *Share of publications with industry* to binary variables to check whether having conducted such activities is relevant at all, irrespective of their intensity. The results from the SUR model (Table A4) do not differ substantially from the main specification. The binary operationalization of the *Work experience outside academia* is again positive and significant, but the *Share of publications with industry* turns positive and significant at the 10% level as well. This gives some small indication that relational capital and ties to industry also influence the recognition of transfer opportunities, in line with our third hypothesis.

5 Discussion and conclusion

The transfer of knowledge and technology from academia into industrial application is usually understood as a process (Fabiano et al., 2020; Maresova et al., 2019). While most research focuses on the end of the process (e.g. Abreu & Grinevich, 2013; Audretsch et al., 2012; Battistella et al., 2016; Bonaccorsi et al., 2014; de Fuentes & Dutrénit, 2012; D'Este et al., 2019), we focus on the initiation of transfer activities at the very beginning of the process. We conceptualize the initiation as a simultaneous recognition of a transfer opportunity and the respective choice of a transfer channel to seize the recognized opportunity. We base our reasoning on opportunity recognition in entrepreneurship (e.g. Ardichvili & Cardozo, 2000; Ardichvili et al., 2003; Baron & Ensley, 2006; George et al., 2016b; Shane, 2003) and generalize it for transfer activities by scientists who can seize their opportunity via different transfer channels (S-I collaboration, IPR, and Spin-off) (Abreu & Grinevich, 2013; Fabiano et al., 2020; Haeussler & Colyvas, 2011). We hypothesize on several factors that influence the scientists' recognition of a transfer opportunity as well as the choice of transfer channel. For the recognition of a transfer opportunity, we hypothesize that prior academic and prior non-academic knowledge, scientific quality and relationships to industry actors are relevant. For the channel choice, we hypothesize that scientists' research orientation, their willingness to take risks and the presence of role models shape their choice for a transfer channel. To test our hypotheses, we conduct a novel, representative survey of scientists in the German state of Thuringia. We apply seemingly unrelated regressions (SUR) (Roodman, 2011) to simultaneously estimate the antecedents of transfer opportunity recognition as well as the factors of channel choice for three transfer channels. SUR allows us to take account the selection into having a transfer opportunity recognition as well as the possibility to choose multiple channels.

On a descriptive level, we observe that less than half of the scientists recognize a transfer opportunity. This result indicates that a substantial share of scientists deems their generated knowledge not relevant or applicable for application outside academia (Amara et al., 2019). Related research shows that many scientists have little awareness and low intention to engage in transfer activities with industry (Huyghe & Knockaert, 2015; Neves & Brito, 2020). Among the scientists who have recognized an opportunity, the highest frequency is in S-I collaboration with more than 80%, while IPR or spin-off creation are chosen by slightly less than 50% each. Furthermore, more than 50% of the scientists recognize opportunities for more than one channel and about a quarter for all the channels. This finding is in line with results from D'Este and Patel (2007) and Iorio et al. (2017). Similar frequencies of channels choice are reported in surveys by Llopis et al. (2018) and D'Este et al. (2019), but they assess the implementation of transfer activities at the end of the process. However, their proportions of scientists who implemented a transfer activity is substantially smaller than the ones who recognize a transfer opportunity in our data, highlighting the difference between examining KTT at the beginning or at the end of the process, since many transfer opportunities do not succeed along the process (Cantner et al., 2021).

Our regression results for the transfer opportunity recognition show that prior academic and prior non-academic knowledge are highly relevant for the recognition of an opportunity. While previous findings already highlighted the importance of research productivity for successful transfer activities (Bekkers & Bodas Freitas, 2008; Garcia et al., 2020; Haeussler & Colyvas, 2011), our results show that the generated scientific knowledge is a prerequisite to recognize opportunities in the first place. Furthermore, our results show that it is not only the scientific knowledge a scientist generated and possesses but also that knowledge gained from activities and experiences in other domains than academia which increase the probability to recognize transfer opportunities, similar to related findings about entrepreneurial opportunity recognition (Cliff et al., 2006; Corner & Ho, 2010). Contrary to the amount of knowledge a scientist possesses, scientific quality has a negative impact on the recognition of transfer opportunities. Going against our hypothesis, the result shows that qualitatively excellent scientists are less likely to recognize a transfer opportunity, which is, however, in line with the ambiguity of the relationship between scientific quality and transfer activities in general, as discussed, for example, by Perkmann et al. (2021). Explanations for this relationship can be that qualitatively excellent scientists are so strongly embedded in their academic domain and the respective norms and logics that they are hardly or not at all receptive to transfer activities (Sauermann & Stephan, 2013). Furthermore, the measurement of scientific quality is skewed towards basic research and attributes a lower value to applied or transfer-relevant research (Waltman et al., 2013). With respect to the influence of previous scientific engagement with industry actors on the recognition of a transfer opportunity, we find ambiguous results. While we find no effect for the magnitude of the interaction, our robustness test gives some indication that having done such interaction or not can matter. Nevertheless, we do not find strong support for such a relationship, which is contrary to previous studies focusing on the implementation of transfer activities (Landry et al., 2007; Landry et al., 2010). It indicates that relational capital to industry might be of higher relevance in the later phases of the transfer process, as shown by Hayter (2016), but not at its initiation.

Regarding the factors influencing the choice of the transfer channel, our results show that the scientist's research orientation has some relevance. A stronger orientation toward basic research increases the probability of a scientist to pursue the opportunity through the spin-off channel. This indicates that such kind of knowledge needs to be commercialized with a long-term perspective, meaning that the development can take years until it is ready for the market (Agarwal & Bayus, 2002; Müller, 2010; Vohora et al., 2004). Examples are recent spin-offs in pharmaceuticals such as BioNTech, which was founded in 2008 and just recently launched a product (Senior, 2020). However, contrary to our hypothesis, we do not observe that scientists with an orientation towards basic research choose S-I collaboration to realize the opportunity. Scientists who are more oriented towards basic research are therefore less concerned with practically relevant questions, which could make it difficult for them to formulate a transfer idea into a collaborative project with industrial partners (Bartunek & Rynes, 2014; Stokes, 1997). Additionally, they most closely embody the image of a traditional scientist who sees a clearly separating boundary between academia and industry and therefore might fundamentally avoid collaborating with industry actors (Lam, 2010; Merton, 1968). With respect to the orientation towards applied research, the results show that it increases the probability to choose the IPR channel as hypothesized. However, we do not find this relationship with the spin-off channel and, thus, do not find support for our hypothesis. One reason for this could be that transfer opportunities from application-oriented researchers more often have a clear technological character, which scientists want to protect as IPR before it is used later in the transfer process as the basis for a spin-off (Leitner et al., 2021; Vohora et al., 2004; Wood, 2011).

We furthermore hypothesized that the channels have different risks associated with them and our results support such a relationship. We find a strong relationship between an individual's risk willingness and the choice of the spin-off channel. Since a scientist must be willing to accept high opportunity costs, e.g. change in tasks, foregone salary and personal financial investment to engage in founding a firm (Arza, 2010; Muscio et al., 2016), only risk-taking scientists choose this channel. For the other two channels which have no substantial costs but potential rewards, the risk willingness does not matter. Besides a scientist's personal characteristics, also the environment and especially role models influence the choice of transfer channel. Role models for IPR and spin-off channels show a positive influence on the choice of the respective channel. The latter results are in line with findings for non-academic entrepreneurship (Ozgen & Baron, 2007; Scherer et al., 1989). With respect to IPR, role models can signal the benefits of such activities, potentially in terms of reputation or financial rewards. However, the role models for the S-I collaboration channel show a negative effect. While this finding seems puzzling, there are arguments for negative role models and certain attributes or behavior which shall be rejected (Gibson, 2004). Since S-I collaboration can be perceived as a "necessary evil" to finance research on the costs of freedom of science and delay or even suppression of scientific publication (see, e.g. Ankrah et al., 2013; Gerbin & Drnovsek, 2020; Geuna & Nesta, 2006). Nevertheless, the result contradicts our initial hypothesis.

Besides our main findings, the results reveal additional interesting insights. First, the control variables show that gender disparities are striking. While there is no difference in the likelihood to recognize an opportunity, female scientists are more likely to choose S-I collaboration and less likely to choose the spin-off channel, in line with previous findings (Abreu & Grinevich, 2017; D'Este et al., 2019). Second, disciplinary differences, in terms of a lower likelihood for Humanities and Social Sciences to recognize a transfer opportunity, exist. However, for Humanities, if an opportunity emerges, the S-I collaboration channel will be chosen with a lower likelihood, while the spin-off channel has a much higher likelihood. The high relevance of academic entrepreneurship in the humanities has been discussed already, e.g., by Pilegaard et al. (2010). Third, the interrelationship between the channel choices reveals that there is a negative correlation between choosing the S-I collaboration channel and the spin-off channel. This indicates that scientists consider the two channels as diametrical, which has been indicated already by Barbieri et al. (2018). An underlying reason could be the intention to exploit knowledge personally and to not share it with potential competitors from the industry.

We contribute with our findings to the understanding of the very beginning, the initiation, of the KTT process from an academic perspective. We provide a conceptualization of the transfer initiation phase with a scientist's simultaneous recognition of a transfer opportunity and the channel choice. We generalize the concept of opportunity recognition, from the entrepreneurship literature to the context of academia to industry transfer, and refine the overall research on the KTT process with a focus on the transfer initiation phase. Analyzing the initiation of the transfer process allows us to capture the whole recognized transfer potential, which then enables us to understand the preconditions required to recognize transfer opportunities, irrespective of their further development along the transfer process. This perspective complements the output-oriented literature that focuses on the results from the transfer process and reveals differences in the relevance of influential factors. Our result that heterogeneity in prior knowledge, in our case academic and non-academic prior knowledge, is decisive to recognize an opportunity and can be associated with the importance of knowledge recombination across knowledge domains and its high relevance to start the KTT process. Contributing to research on conflicting logis in academia, we show that researchers who produce high-impact knowledge are less likely to recognize an opportunity, indicating that the conflicting logics are relevant already at the beginning of the transfer process. With respect to the factors that influence the transfer channel choice, the insight that different kinds of research orientation favor different transfer channels gives a finer-grained picture of the underlying mechanisms of transfer channel choices. Our results with respect to the role models show that the social context is already relevant at the beginning of the transfer process, paving the way for a potential pursuit of the transfer opportunity. Peer effects can influence channel choices, but this can happen in both directions. Lastly, our results on risk willingness contribute to the growing literature on personality characteristics and transfer activity. From a methodological point of view, we suggest new instruments to account for potential selection bias in recognizing transfer opportunities as well as accounting for the choice of multiple transfer channels.

Our findings can also be used to derive implications for policy makers and research management to foster transfer activities. First, since heterogeneous knowledge is relevant to recognize opportunities, the possibility for scientists to work with or in industry should be eased and fostered. Industry-related experience would lead to a better understanding of industrial needs and commercial potential. Second, our results show that especially scientists with high-quality knowledge do not recognize transfer opportunities. Programs that raise their awareness or better incentive structures in the academic reward system could help them realize transfer potential. Third, transfer managers and policymakers should consider in their support that scientists can have different research orientations and provide tailor-made programs for different kinds of research activity. Fourth, role models are a decisive factor and prominent examples can be used to raise awareness and serve as best-practice examples or even mentorship on how to transfer via a specific channel. Lastly, the high risk involved in spin-off attempts should be better cushioned, enabling more ideas with commercial potential to find their way into economic application. To lower the risk of foregone academic rewards, one approach could be to reduce time constraints for spin-off projects and grant scientists an entrepreneurial leave term to realize their idea. Similarly, spin-off activities should be acknowledged for academic qualification, too.

Our analysis is subject to several limitations, serving as starting points for further research. First, for the transfer opportunity recognition, we cannot disentangle whether the opportunity was triggered by a push from academia, by a pull from industry or whether it was a mix of both (D'Este et al., 2019; Nemet, 2009; Walsh, 1984). Understanding the triggering event can provide additional insights into opportunity recognition. Second, we cannot elaborate on scientists' willingness to pursue the recognized opportunity. Scientists may be fundamentally unwilling to engage in such activities but may still see transfer potential in their research and vice versa. Third, since we focus on the initiation of the transfer process, we cannot make any statements about whether scientists change the transfer channel in the course of the pursuit or whether a follow-up opportunity develops from a pursuit (Hayter et al., 2020). Lastly, the transfer opportunities we observed are not assessed based on their quality or feasibility. We cannot include an assessment regarding the commercializability of the opportunity in the analysis and how this affects the further course of the transfer process.

Besides these limitations, further research on the initiation of the transfer process should investigate the quality and frequency of recognized transfer opportunities and whether a higher intensity leads to a larger probability of high-quality opportunities. Furthermore, our results show that risk willingness is decisive for the channel choice, but other personality traits could influence opportunity recognition and channel choice as well. Understanding the influence of personality characteristics in more detail would make further contributions to the psychological foundations of science commercialization (Hmieleski & Powell, 2018). In more general terms, our conceptualization of the transfer initiation can be applied to other transfer channels, including informal transfer channels (Grimpe & Hussinger, 2013; Schaeffer et al., 2020) and other aims of transfer, such as societal engagement (Benneworth & Cunha, 2015; Bornmann, 2013; Fini et al., 2018). For such extensions, other factors can be relevant for the recognition of opportunities and the respective choice of channels.

Appendix

Variable construction

Table A1: List of variables and their construction.

Variable	**Construction**	**Data type**
Dependent variables		
TOR (=1)	Aggregation of the three variables for channel choice	Binary
S-I Collaboration	Survey item: *Development of an idea for a cooperation with company participation, i.e. identification of a research question or problem for which a cooperation between universities/research institutes and companies could be helpful*	Binary
IPR (=1)	Survey item: *Identification of an idea or invention that can be attributed to potential commercial exploitation or can be legally protected*	Binary
Spin-off (=1)	Survey item: *Development of an idea to found a firm, e.g. discussion of the idea with others, assessment of the economic potential or application of creative techniques?*	Binary
Antecedents of transfer opportunity recognition		
Number of publications	Data collected from Web of Science and Scopus	Numerical
Work experience outside academia	Survey: *How many years of work experience outside the public science sector have you gained overall?* (5 categories (in years): 1: =0; 2: < 1; 3: >1 ... <3; 4: >3 ... <10 ; 5: >10)	Numerical
Average impact factor	Average of the scientists journals' Source Normalized Impact per Paper	Numerical
Share of publications with industry	Share of scientist's publications in co-authorship with at least one firm	Numerical
Organizational transfer orientation	Share of respondents with a TOR from same organization as focal respondent	Numerical
Internal funding	Survey item: *How is your current position financed?*	Binary
Factors of channel choice		
Basic research	Survey item: *Please assess the extent to which you contribute with your research to scientific progress in your discipline and thus shift the research frontier in your discipline further.* (4-point Likert-scale: ”Not at all” to ”To a large extent”)	Numerical
Applied research	Survey item: *Please assess the extent to which your research is targeted towards practical application.* (4-point Likert-scale: ”Not at all” to ”To a large extent”)	Numerical
Risk willingness	Survey item: *How do you see yourself: Are you generally a person who is fully prepared to take risks or are you trying to avoid risks?* as used by SOEP-IS Group (2014, p. 36) (11-point Likert scale)	Numerical
Role models: S-I collaboration	Share of respondents from same faculty/organizational unit as focal respondent with at least one successful S-I collaboration (Survey item: *Realisation or participation in a research cooperation with company participation.*	Numerical
Role models: IPR	Share of respondents from same faculty/organizational unit as focal respondent with at least one successful IPR (Survey item: *Selling or licensing of an idea or invention e.g. selling a patent to a company.*	Numerical
Role models: Spin-off	Share of respondents from same faculty/organizational unit as focal respondent with at least one successful academic spin-off (Survey item: *Completed foundation of a firm, i.e. the launch of business activities.*	Numerical
Control variables		
Professor (=1)	Survey item: *Which of the following options describes your current position best?*	Binary
Female (=1)	Survey item: *Please indicate your gender.*	Binary
Organizational focus	Distinction of organizations between 1: Basic, 2: Between basic and applied, 3: Applied, following (BMBF, 2014)	Categorical
Discipline	Data collected from participants webpages.	Categorical

Robustness tests

Table A2: Heckprobit estimation of each channel choice separately.

	S-I Collaboration (=1)		IPR (=1)		Spin-off (=1)	
	(1) Selection (TOR)	(2) Outcome	(3) Selection (TOR)	(4) Outcome	(5) Selection (TOR)	(6) Outcome
Antecedents of transfer opportunity recognition						
Number of publications	0.221***		0.231***		0.222***	
	(0.038)		(0.037)		(0.039)	
Work experience outside academia	0.093***		0.096***		0.107***	
	(0.031)		(0.032)		(0.030)	
Average impact factor	-0.217***		-0.230***		-0.226***	
	(0.074)		(0.072)		(0.076)	
Share of publications with industry	0.507		0.531		0.564	
	(0.353)		(0.356)		(0.373)	
Exclusion restrictions						
Organizational transfer orientation	2.066***		2.061***		2.025***	
	(0.308)		(0.308)		(0.313)	
Internal funding (=1)	-0.271***		-0.237***		-0.257***	
	(0.085)		(0.091)		(0.090)	
Factors of channel choice						
Basic research		-0.096		0.092		0.213**
		(0.088)		(0.079)		(0.084)
Applied research		0.127		0.254***		0.060
		(0.083)		(0.084)		(0.084)
Risk willingness		-0.010		-0.012		0.097***
		(0.030)		(0.027)		(0.029)
Role models: Collaboration		-0.612*				
		(0.367)				
Role models: IPR				1.407***		
				(0.523)		
Role models: Spin-off						1.623**
						(0.640)
Control variables						
Professor (=1)	0.170	0.250	0.132	0.022	0.159	0.001
	(0.124)	(0.166)	(0.125)	(0.148)	(0.126)	(0.150)
Female (=1)	-0.024	0.269*	-0.014	-0.210	-0.018	-0.329**
	(0.086)	(0.138)	(0.086)	(0.130)	(0.086)	(0.130)
Discipline: Engineering	-0.021	0.151	-0.024	-0.005	-0.031	-0.023
	(0.159)	(0.247)	(0.158)	(0.193)	(0.159)	(0.204)
Discipline: Humanities	-0.412**	-0.813**	-0.414**	0.366	-0.433**	1.040***
	(0.200)	(0.399)	(0.200)	(0.318)	(0.201)	(0.395)
Discipline: Life Sciences	-0.255	-0.256	-0.255	0.397	-0.254	0.414
	(0.174)	(0.280)	(0.175)	(0.245)	(0.175)	(0.272)
Discipline: Medicine	-0.148	-0.307	-0.163	0.397	-0.166	0.163
	(0.185)	(0.292)	(0.185)	(0.245)	(0.187)	(0.270)
Discipline: Physics and Chemistry	-0.063	-0.098	-0.049	0.412**	-0.044	0.210
	(0.161)	(0.226)	(0.160)	(0.196)	(0.161)	(0.211)
Discipline: Social Sciences	-0.313*	-0.191	-0.310*	0.136	-0.324**	0.122
	(0.160)	(0.277)	(0.161)	(0.246)	(0.161)	(0.268)
Organizational focus: basic	-0.007	-0.191	-0.009	-0.011	-0.012	-0.383*
	(0.131)	(0.201)	(0.131)	(0.194)	(0.131)	(0.208)
Organizational focus: applied	0.112	-0.038	0.119	-0.120	0.110	0.070
	(0.123)	(0.188)	(0.123)	(0.152)	(0.124)	(0.165)
Constant	-1.183***	1.599***	-1.206***	-0.896**	-1.181***	-1.732***
	(0.219)	(0.422)	(0.219)	(0.437)	(0.221)	(0.435)
ε_C	-0.710***		-0.506**		0.193	
	(0.198)		(0.211)		(0.265)	
N	1,149		1,149		1,149	
Pseudo Log-Likelihood	-893.0884		-997.1153		-1002.761	
Wald Chi^2	20.13		25.15		47.64	

Note: Robust standard errors in parentheses. Significance levels at *** p<0.01, ** p<0.05, * p<0.1.

Table A3: SUR estimation of a sub sample excluding scientists from Social Sciences and Humanities.

	Selection	Outcomes		
	(1) TOR (=1)	(2) S-I Collaboration (=1)	(3) IPR (=1)	(4) Spin-off (=1)
Antecedents of transfer opportunity recognition				
Number of publications	0.256***			
	(0.045)			
Work experience outside academia	0.109***			
	(0.040)			
Average impact factor	-0.273***			
	(0.089)			
Share of publications with industry	0.428			
	(0.405)			
Exclusion restrictions				
Organizational transfer orientation	2.451***			
	(0.394)			
Internal funding	-0.330***			
	(0.122)			
Factors of channel choice				
Basic research		-0.032	0.048	0.207**
		(0.105)	(0.092)	(0.095)
Applied research		-0.013	0.213**	0.134
		(0.097)	(0.098)	(0.097)
Risk willingness		-0.016	-0.030	0.075**
		(0.034)	(0.031)	(0.032)
Role models: S-I Collaboration		-0.763*		
		(0.438)		
Role models: IPR			1.781***	
			(0.643)	
Role models: Spin-off				1.146
				(0.731)
Control variables				
Professor (=1)	0.185	0.193	0.074	0.186
	(0.165)	(0.191)	(0.177)	(0.168)
Female (=1)	-0.027	0.304*	-0.325**	-0.327**
	(0.104)	(0.164)	(0.154)	(0.146)
Discipline: Engineering	-0.027	0.136	-0.027	-0.044
	(0.164)	(0.246)	(0.201)	(0.208)
Discipline: Life Sciences	-0.151	-0.345	0.369	0.501*
	(0.186)	(0.293)	(0.268)	(0.289)
Discipline: Medicine	-0.073	-0.408	0.356	0.133
	(0.202)	(0.286)	(0.260)	(0.277)
Discipline: Physics and Chemistry	0.016	-0.194	0.391*	0.255
	(0.172)	(0.228)	(0.207)	(0.214)
Organizational focus: Basic	-0.090	-0.238	-0.059	-0.502**
	(0.142)	(0.216)	(0.214)	(0.225)
Organizational focus: Applied	0.104	0.105	-0.065	0.014
	(0.156)	(0.221)	(0.181)	(0.194)
Constant	-1.404***	1.997***	-0.682	-1.733***
	(0.254)	(0.498)	(0.535)	(0.527)
	$\varepsilon_{Selection}$	$\varepsilon_{Collaboration}$	ε_{IPR}	$\varepsilon_{Spin-off}$
$\varepsilon_{Collaboration}$	-0.697***			
	(0.202)			
ε_{IPR}	-0.297	0.146		
	(0.345)	(0.135)		
$\varepsilon_{Spin-off}$	0.124	-0.324***	0.222*	
	(0.350)	(0.122)	(0.116)	
N	822			
Pseudo Log-Likelihood	-1172.66			
Wald Chi^2	207.33			

Note: Robust standard errors in parentheses. Significance levels at *** p<0.01, ** p<0.05, * p<0.1.

Table A4: SUR estimation with dummy variables for *Work experience outside academia* and *Publications with industry*

	Selection	Outcomes		
	(1) TOR (=1)	(2) S-I Collaboration (=1)	(3) IPR (=1)	(4) Spin-off (=1)
Antecedents of transfer opportunity recognition				
Number of publications	0.198***			
	(0.040)			
Work experience outside academia (=1)	0.221**			
	(0.096)			
Average impact factor	-0.204***			
	(0.073)			
Publications with industry (=1)	0.227*			
	(0.124)			
Exclusion restrictions				
Organizational transfer orientation	2.070***			
	(0.323)			
Internal funding (=1)	-0.241***			
	(0.090)			
Factors of channel choice				
Basic research		-0.091	0.092	0.214**
		(0.089)	(0.079)	(0.085)
Applied research		0.136	0.268***	0.056
		(0.085)	(0.083)	(0.083)
Risk willingness		-0.001	-0.011	0.097***
		(0.030)	(0.027)	(0.029)
Role models: S-I Collaboration		-0.601*		
		(0.352)		
Role models: IPR			1.525***	
			(0.553)	
Role models: Spin-off				1.311**
				(0.614)
Control variables				
Professor (=1)	0.156	0.270	0.042	0.025
	(0.123)	(0.166)	(0.150)	(0.149)
Female (=1)	-0.018	0.282**	-0.219*	-0.325**
	(0.085)	(0.139)	(0.131)	(0.129)
Discipline: Engineering	-0.017	0.183	-0.002	-0.050
	(0.159)	(0.243)	(0.194)	(0.202)
Discipline: Humanities	-0.381*	-0.845**	0.378	0.966**
	(0.199)	(0.389)	(0.328)	(0.402)
Discipline: Life Sciences	-0.257	-0.251	0.403	0.354
	(0.176)	(0.281)	(0.249)	(0.276)
Discipline: Medicine	-0.175	-0.331	0.399	0.096
	(0.187)	(0.285)	(0.245)	(0.265)
Discipline: Physics and Chemistry	-0.076	-0.113	0.416**	0.172
	(0.162)	(0.224)	(0.198)	(0.208)
Discipline: Social Sciences	-0.310*	-0.173	0.126	0.053
	(0.161)	(0.273)	(0.245)	(0.262)
Organizational focus: Basic	0.001	-0.176	-0.005	-0.378*
	(0.131)	(0.205)	(0.194)	(0.207)
Organizational focus: Applied	0.154	-0.047	-0.129	0.092
	(0.126)	(0.186)	(0.154)	(0.162)
Constant	-1.205***	1.452***	-0.969**	-1.728***
	(0.224)	(0.419)	(0.434)	(0.404)
	$\varepsilon_{Selection}$	$\varepsilon_{Collaboration}$	ε_{IPR}	$\varepsilon_{Spin-off}$
$\varepsilon_{Collaboration}$	-0.647***			
	(0.162)			
ε_{IPR}	-0.483**	0.195*		
	(0.223)	(0.115)		
$\varepsilon_{Spin-off}$	0.269	-0.451***	0.139	
	(0.243)	(0.092)	(0.131)	
N	1,149			
Pseudo Log-Likelihood	-1519.3906			
Wald Chi^2	263.97			

Note: Robust standard errors in parentheses. Significance levels at *** p<0.01, ** p<0.05, * p<0.1.

Supplementary material

Sample representativeness

Table S1: Non-response analysis.

Variable	Approached (%)	Sample (%)	Difference
Professor (=1)	16.49	18.28	1.79
Female (=1)	37.56	36.73	-0.83
Organizational focus: Basic	16.06	15.23	-0.83
Organizational focus: Between basic and applied	63.85	63.97	0.12
Organizational focus: Applied	20.09	20.80	0.71
Computer Science & Mathematics	10.11	10.53	0.42
Engineering	14.04	16.36	2.32**
Humanities	12.78	9.66	-3.12***
Life Science	13.50	14.97	1.47
Medicine	15.65	9.75	-5.9***
Physics & Chemistry	18.87	19.67	0.8
Social Sciences	15.05	19.06	4.01***
N	7785	1149	

Note: Group comparison based on Wilcoxon rank-sum tests.
Significance levels at *** p<0.01, ** p<0.05, * p<0.1.

Table S2: Representativeness.

Variable	Germany (Universities) (%)	Sample (Universities) (%)
Professor (=1)	18.63	20.99
Female (=1)	40.20	37.27

Note: The comparison is only between the respondents affiliated to universities and universities of applied sciences, not to research organizations.
Data for the overall population of scientists at universities in Germany is taken from (Statistisches Bundesamt, 2020).

Research organizations in Thuringia

Table S3: List of approached organizations and their research focus.

Number	Organization	Organizational focus
	Universities and universities of applied sciences	
1	Bauhaus-Universität Weimar	between basic and applied
2	Duale Hochschule Gera-Eisenach	applied
3	Ernst-Abbe-Hochschule Jena	applied
4	Fachhochschule Erfurt	applied
5	Friedrich-Schiller-Universität Jena	between basic and applied
6	Hochschule für Musik FRANZ LISZT Weimar	applied
7	Hochschule Nordhausen	applied
8	Hochschule Schmalkalden	applied
9	SRH Hochschule für Gesundheit	applied
10	Technische Universität Ilmenau	between basic and applied
11	Universität Erfurt	between basic and applied
	Research institutes	
12	Forschungsinstitut für Mikrosensorik	applied
13	Forschungszentrum für Medizintechnik und Biotechnologie	applied
14	Fraunhofer-Institut für Angewandte Optik und Feinmechanik	applied
15	Fraunhofer-Institut für Digitale Medientechnologie	applied
16	Fraunhofer-Institut für Keramische Technologien und Systeme	applied
17	Fraunhofer-Institut für Optronik, Systemtechnik und Bildauswertung Institutsteil Angewandte Systemtechnik	applied
18	Friedrich-Loeffler-Institut für bakterielle Infektionen und Zoonosen	applied
19	Friedrich-Loeffler-Institut für molekulare Pathogenese	applied
20	Gesellschaft für Fertigungstechnik und Entwicklung	applied
21	Günter-Köhler-Institut für Fügetechnik und Werkstoffprüfung	applied
22	Helmholtz-Institut Jena	basic
23	Innovent	applied
24	Institut für Angewandte Bauforschung	applied
25	Institut für Bioprozess- und Analysenmesstechnik Heiligenstadt	applied
26	Institut für Datenwissenschaften	applied
27	Institut für Mikroelektronik- und Mechatronik-Systeme	applied
28	Leibniz-Institut für Alternsforschung - Fritz-Lipmann-Institut e.V.	basic
29	Leibniz-Institut für Naturstoff-Forschung und Infektionsbiologie Hans-Knöll-Institut	basic
30	Leibniz-Institut für Photonische Technologien	basic
31	Materialforschungs- und -prüfanstalt	applied
32	Max-Planck-Institut für Biogeochemie	basic
33	Max-Planck-Institut für chemische Ökologie	basic
34	Max-Planck-Institut für Menschheitsgeschichte	basic
35	Textilforschungsinstitut Thüringen-Vogtland	applied
36	Thüringer Landessternwarte Tautenburg	basic
37	Thüringisches Institut für Textil- u. Kunststoff-Forschung	applied

Correlation tables

Table S4: Pearson correlation coefficients all scientists (N=1149).

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	TOR (=1)																		
2	Number of publications (log)	0.15*																	
3	Average impact factor	-0.01	0.62*																
4	Work experience outside academia	0.12*	-0.17*	-0.21*															
5	Share of publications with industry	0.13*	0.08*	0.06*	0.05														
6	Organizational transfer orientation	0.33*	-0.04	-0.08*	0.10*	0.22*													
7	Internal funding (=1)	-0.06*	0.17*	0.04	0.07*	-0.04	-0.08*												
8	Professor (=1)	0.08*	0.29*	0.07*	0.19*	0.00	-0.02	0.37*											
9	Female (=1)	-0.11*	-0.18*	-0.07*	-0.11*	-0.06*	-0.11*	-0.05	-0.12*										
10	Discipline: Computer Science and Mathematics	0.11*	0.01	-0.02	0.00	0.06*	0.21*	-0.04	-0.01	-0.14*									
11	Discipline: Engineering	0.18*	-0.14*	-0.15*	0.15*	0.16*	0.44*	-0.03	0.03	-0.08*	-0.15*								
12	Discipline: Humanities	-0.13*	-0.16*	-0.13*	0.11*	-0.05	-0.25*	-0.04	0.01	0.09*	-0.11*	-0.14*							
13	Discipline: Life Sciences	-0.06*	0.09*	0.15*	-0.13*	-0.01	-0.10*	-0.03	-0.06*	0.06*	-0.14*	-0.19*	-0.14*						
14	Discipline: Medicine	-0.04	0.16*	0.12*	0.00	-0.03	-0.18*	0.10*	0.00	0.12*	-0.11*	-0.15*	-0.11*	-0.14*					
15	Discipline: Physics and Chemistry	0.05	0.22*	0.16*	-0.17*	-0.06	-0.03	-0.15*	-0.09*	-0.07*	-0.17*	-0.22*	-0.16*	-0.21*	-0.16*				
16	Discipline: Social Sciences	-0.13*	-0.18*	-0.13*	0.07*	-0.07*	-0.13*	0.20*	0.12*	0.04	-0.17*	-0.21*	-0.16*	-0.20*	-0.16*	-0.24*			
17	Organizational focus: basic	-0.05	0.18*	0.26*	-0.16*	-0.02	-0.15*	-0.12*	-0.13*	0.01	-0.15*	-0.19*	0.05	0.35*	-0.14*	0.25*	-0.21*		
18	Organizational focus: Between basic and applied	-0.11*	-0.01	-0.06*	-0.10*	-0.10*	-0.28*	0.07*	-0.05	0.04	0.16*	-0.17*	-0.03	-0.19*	0.18*	-0.12*	0.23*	-0.57*	
19	Organizational focus: applied	0.18*	-0.15*	-0.16*	0.26*	0.13*	0.47*	0.02	0.18*	-0.05	-0.05	0.37*	-0.01	-0.08*	-0.09*	-0.08*	-0.08*	-0.22*	-0.68*

Note: N=1149. Significance level at * p<0.05.

Table S5: Pearson correlation coefficients for scientists with recognized transfer opportunity (N=504).

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Spin-off (=1)																				
2	S-I Collaboration (=1)	-0.25*																			
3	IPR (=1)	0.14*	0.06																		
4	Applied research	0.04	0.13*	0.16*																	
5	Basic research	0.14*	-0.06	0.08	0.07																
6	Risk willingness	0.17*	-0.01	0.01	0.08	0.17*															
7	Role models Spin-off	0.07	-0.01	0.03	0.02	0.00	-0.02														
8	Role models S-I Collaboration	-0.06	0.12*	0.18*	0.30*	-0.06	-0.03	0.05													
9	Role models IPR	-0.04	0.05	0.22*	0.18*	0.04	-0.01	0.13*	0.49*												
10	Professor (=1)	0.04	0.09*	0.01	0.00	0.09*	0.11*	0.01	-0.10*	-0.09*											
11	Female (=1)	-0.08	0.03	-0.09*	0.00	0.00	-0.09*	0.03	-0.10*	-0.01	-0.07										
12	Discipline: Computer Science and Mathematics	0.00	0.06	0.00	0.12*	0.03	0.00	0.24*	0.17*	0.02	-0.04	-0.13*									
13	Discipline: Engineering	-0.06	0.13*	0.01	0.22*	-0.07	0.02	0.00	0.41*	0.24*	-0.02	-0.04	-0.23*								
14	Discipline: Humanities	0.13*	-0.19*	-0.06	-0.04	0.09*	-0.01	-0.05	-0.30*	-0.16*	-0.02	0.16*	-0.10*	-0.13*							
15	Discipline: Life Sciences	0.02	-0.07	0.00	-0.15*	0.01	0.05	-0.07	-0.12*	-0.09*	0.00	0.07	-0.16*	-0.21*	-0.09*						
16	Discipline: Medicine	-0.02	-0.02	0.00	-0.08	-0.04	0.01	-0.11*	-0.12*	-0.10*	0.08	0.10*	-0.13*	-0.17*	-0.07	-0.12*					
17	Discipline: Physics and Chemistry	0.00	-0.01	0.13*	-0.10*	0.07	-0.02	0.01	0.11*	0.16*	-0.10*	-0.07	-0.22*	-0.30*	-0.12*	-0.20*	-0.16*				
18	Discipline: Social Sciences	-0.01	-0.01	-0.12*	-0.04	-0.06	-0.05	-0.08	-0.41*	-0.25*	0.13*	0.02	-0.16*	-0.22*	-0.09*	-0.15*	-0.12*	-0.21*			
19	Organizational focus: Basic	-0.02	-0.13*	0.02	-0.20*	0.11*	0.02	-0.01	-0.16*	-0.02	-0.11*	-0.01	-0.16*	-0.22*	0.09*	0.40*	-0.12*	0.20*	-0.15*		
20	Organizational focus: Between basic and applied	0.02	0.02	-0.09*	-0.16*	0.03	0.03	-0.01	-0.33*	-0.29*	-0.06	0.01	0.23*	-0.17*	-0.06	-0.23*	0.19*	-0.11*	0.21*	-0.46*	
21	Organizational focus: Applied	0.00	0.08	0.09	0.32*	-0.11*	-0.05	0.02	0.49*	0.33*	0.15*	0.00	-0.14*	0.35*	-0.01	-0.05	-0.11*	-0.03	-0.12*	-0.25*	-0.75*

Note: N=504. Significance level at * p<0.05.

Including the exclusion restrictions in the outcome equations

Table S6: SUR estimation with exclusion restriction in the outcome equations.

	Selection	Outcomes		
	(1) TOR (=1)	(2) S-I Collaboration (=1)	(3) IPR (=1)	(4) Spin-off (=1)
Antecedents of transfer opportunity recognition				
Number of publications	0.236***			
	(0.037)			
Work experience outside academia	0.080			
	(0.052)			
Average impact factor	-0.215**			
	(0.087)			
Share of publications with industry	0.399			
	(0.444)			
Exclusion restrictions				
Organizational transfer orientation	1.998***	1.069	0.113	0.199
	(0.326)	(0.836)	(0.642)	(0.654)
Internal funding (=1)	-0.273***	-0.032	0.147	-0.211
	(0.090)	(0.151)	(0.127)	(0.129)
Factors of channel choice				
Basic research		-0.092	0.095	0.209**
		(0.096)	(0.080)	(0.085)
Applied research		0.142	0.263***	0.044
		(0.092)	(0.084)	(0.082)
Risk willingness		0.005	-0.009	0.096***
		(0.032)	(0.026)	(0.029)
Role models: S-I Collaboration		-1.152**		
		(0.450)		
Role models: IPR			1.432***	
			(0.522)	
Role models: Spin-off				1.331**
				(0.642)
Control variables				
Professor (=1)	0.149	0.355	-0.039	0.145
	(0.127)	(0.235)	(0.179)	(0.182)
Female (=1)	-0.017	0.286*	-0.203	-0.336***
	(0.087)	(0.148)	(0.137)	(0.128)
Discipline: Engineering	-0.016	0.192	-0.015	-0.036
	(0.159)	(0.253)	(0.193)	(0.203)
Discipline: Humanities	-0.410**	-0.986*	0.410	1.005**
	(0.201)	(0.505)	(0.327)	(0.447)
Discipline: Life Sciences	-0.265	-0.297	0.415*	0.365
	(0.176)	(0.320)	(0.247)	(0.294)
Discipline: Medicine	-0.180	-0.271	0.394	0.173
	(0.187)	(0.300)	(0.254)	(0.265)
Discipline: Physics and Chemistry	-0.079	-0.080	0.432**	0.173
	(0.168)	(0.236)	(0.205)	(0.208)
Discipline: Social Sciences	-0.308*	-0.263	0.142	0.105
	(0.161)	(0.333)	(0.252)	(0.289)
Organizational focus: Basic	-0.018	-0.212	-0.018	-0.362*
	(0.131)	(0.216)	(0.192)	(0.207)
Organizational focus: Applied	0.151	-0.102	-0.158	0.061
	(0.133)	(0.209)	(0.167)	(0.173)
Constant	-1.158***	1.057	-1.034	-1.758***
	(0.240)	(0.672)	(0.750)	(0.610)
	$\varepsilon_{Selection}$	$\varepsilon_{Collaboration}$	ε_{IPR}	$\varepsilon_{Spin-off}$
$\varepsilon_{Collaboration}$	-0.456			
	(0.461)			
ε_{IPR}	-0.538*	0.158		
	(0.324)	(0.215)		
$\varepsilon_{Spin-off}$	0.322	-0.462***	0.110	–
	(0.282)	(0.124)	(0.232)	
N		1,149		
Pseudo Log-Likelihood		-1516.893		
Wald Chi^2		262.97		

Note: Robust standard errors in parentheses. Significance levels at *** p<0.01, ** p<0.05, * p<0.1.

References

Abreu, M., & Grinevich, V. (2013). The nature of academic entrepreneurship in the UK: Widening the focus on entrepreneurial activities. *Research Policy*, *42*(2), 408–422. https://doi.org/10.1016/j.respol.2012.10.005

Abreu, M., & Grinevich, V. (2017). Gender patterns in academic entrepreneurship. *The Journal of Technology Transfer*, *42*(4), 763–794. https://doi.org/10.1007/s10961-016-9543-y

Achtziger, A., & Gollwitzer, P. M. (2018). Motivation and Volition in the Course of Action (J. Heckhausen & H. Heckhausen, Eds.). In J. Heckhausen & H. Heckhausen (Eds.), *Motivation and Action*. Cham, Springer International Publishing. https://doi.org/10.1007/978-3-319-65094-4_12

Agarwal, R., & Bayus, B. L. (2002). The Market Evolution and Sales Takeoff of Product Innovations. *Management Science*, *48*(8), 1024–1041. https://doi.org/10.1287/mnsc.48.8.1024.167

Aghion, P., Dewatripont, M., & Stein, J. C. (2008). Academic freedom, private-sector focus, and the process of innovation. *The RAND Journal of Economics*, *39*(3), 617–635. https://doi.org/10.1111/j.1756-2171.2008.00031.x

AL-Tabbaa, O., & Ankrah, S. (2016). Social capital to facilitate 'engineered' university–industry collaboration for technology transfer: A dynamic perspective. *Technological Forecasting and Social Change*, *104*, 1–15. https://doi.org/10.1016/j.techfore.2015.11.027

Amara, N., Olmos-Peñuela, J., & Fernández-de-Lucio, I. (2019). Overcoming the "lost before translation" problem: An exploratory study. *Research Policy*, *48*(1), 22–36. https://doi.org/10.1016/j.respol.2018.07.016

Ambos, T. C., Mäkelä, K., Birkinshaw, J., & D'Este, P. (2008). When Does University Research Get Commercialized? Creating Ambidexterity in Research Institutions. *Journal of Management Studies*, *45(8)*, 1424–1447. https://doi.org/10.1111/J.1467-6486.2008.00804.X

Andries, P., Clarysse, B., & Costa, S. (2021). Technology ventures' engagement of external actors in the search for viable market applications: On the relevance of Technology Broadcasting and Systematic Validation. *Journal of Business Venturing*, *36*(6), 106145. https://doi.org/10.1016/j.jbusvent.2021.106145

Ankrah, S. N., Burgess, T. F., Grimshaw, P., & Shaw, N. E. (2013). Asking both university and industry actors about their engagement in knowledge transfer: What single-group studies of motives omit. *Technovation*, *33*(2-3), 50–65. https://doi.org/10.1016/j.technovation.2012.11.001

Ankrah, S., & AL-Tabbaa, O. (2015). Universities–industry collaboration: A systematic review. *Scandinavian Journal of Management*, *31*(3), 387–408. https://doi.org/10.1016/j.scaman.2015.02.003

Ardichvili, A., & Cardozo, R. N. (2000). A model of the entrepreneurial opportunity recognition process. *Journal of Enterprising Culture*, *8*(2), 103–119. https://doi.org/10.1142/S0218495800000073

Ardichvili, A., Cardozo, R. N., & Ray, S. (2003). A theory of entrepreneurial opportunity identification and development. *Journal of Business Venturing*, *18*(1), 105–123. https://doi.org/10.1016/S0883-9026(01)00068-4

Arentz, J., Sautet, F., & Storr, V. (2013). Prior-knowledge and opportunity identification. *Small Business Economics*, *41*(2), 461–478. https://doi.org/10.1007/s11187-012-9437-9

Armstrong, J. S., & Overton, T. S. (1977). Estimating Nonresponse Bias in Mail Surveys. *Journal of Marketing Research*, *14*(3), 396–402. https://doi.org/10.1177/002224377701400320

Arza, V. (2010). Channels, benefits and risks of public–private interactions for knowledge transfer: conceptual framework inspired by Latin America. *Science and Public Policy*, *37*(7), 473–484. https://doi.org/10.3152/030234210X511990

Aschhoff, B., & Grimpe, C. (2014). Contemporaneous peer effects, career age and the industry involvement of academics in biotechnology. *Research Policy*, *43*(2), 367–381. https://doi.org/10.1016/j.respol.2013.11.002

Åstebro, T., Braunerhjelm, P., & Broström, A. (2013). Does academic entrepreneurship pay? *Industrial and Corporate Change*, *22*(1), 281–311. https://doi.org/10.1093/icc/dts044

Audretsch, D. B., Bozeman, B., Combs, K. L., Feldman, M., Link, A. N., Siegel, D. S., Stephan, P., Tassey, G., & Wessner, C. (2002). The Economics of Science and Technology. *The Journal of Technology Transfer*, *27*(2), 155–203. https://doi.org/10.1023/A:1014382532639

Audretsch, D. B., Hülsbeck, M., & Lehmann, E. E. (2012). Regional competitiveness, university spillovers, and entrepreneurial activity. *Small Business Economics*, *39*(3), 587–601. https://doi.org/10.1007/s11187-011-9332-9

Balasubramanian, S., Yang, Y., & Tello, S. (2020). Does university entrepreneurial orientation matter? Evidence from university performance. *Strategic Entrepreneurship Journal*, *14*(4), 661–682. https://doi.org/10.1002/sej.1341

Barbieri, E., Rubini, L., Pollio, C., & Micozzi, A. (2018). What are the trade-offs of academic entrepreneurship? An investigation on the Italian case. *The Journal of Technology Transfer*, *43*(1), 198–221. https://doi.org/10.1007/s10961-016-9482-7

Baron, R. A. (2007). Behavioral and cognitive factors in entrepreneurship: entrepreneurs as the active element in new venture creation. *Strategic Entrepreneurship Journal*, *1*(1-2), 167–182. https://doi.org/10.1002/sej.12

Baron, R. A., & Ensley, M. D. (2006). Opportunity Recognition as the Detection of Meaningful Patterns: Evidence from Comparisons of Novice and Experienced Entrepreneurs. *Management Science*, *52*(9), 1331–1344. https://doi.org/10.1287/mnsc.1060.0538

Bartunek, J. M., & Rynes, S. L. (2014). Academics and practitioners are alike and unalike: The paradoxes of academic-practitioner relationships. *Journal of Management*, *40*(5), 1181–1201. https://doi.org/10.1177/0149206314529160

Bar-Zakay, S. N. (1971). Technology transfer model. *Technological Forecasting and Social Change*, *2*(3-4), 321–337. https://doi.org/10.1016/0040-1625(71)90009-6

Battistella, C., de Toni, A. F., & Pillon, R. (2016). Inter-organisational technology/knowledge transfer: a framework from critical literature review. *The Journal of Technology Transfer*, *41*(5), 1195–1234. https://doi.org/10.1007/s10961-015-9418-7

Beierlein, C., Kovaleva, A., Kemper, C. J., & Rammstedt, B. (2014). *Eine Single-Item-Skala zur Erfassung von Risikobereitschaft: Die Kurzskala Risikobereitschaft-1 (R-1)* (Vol. 2014/34). Mannheim.

Bekkers, R., & Bodas Freitas, I. M. (2008). Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? *Research Policy*, *37*(10), 1837–1853. https://doi.org/10.1016/j.respol.2008.07.007

Benneworth, P., & Cunha, J. (2015). Universities' contributions to social innovation: reflections in theory & practice. *European Journal of Innovation Management*, *18*(4), 508–527. https://doi.org/10.1108/EJIM-10-2013-0099

Bercovitz, J., & Feldman, M. (2006). Entpreprenerial Universities and Technology Transfer: A Conceptual Framework for Understanding Knowledge-Based Economic Development. *The Journal of Technology Transfer*, *31*(1), 175–188. https://doi.org/10.1007/s10961-005-5029-z

Bercovitz, J., & Feldman, M. (2008). Academic Entrepreneurs: Organizational Change at the Individual Level. *Organization Science*, *19*(1), 69–89. https://doi.org/10.1287/orsc.1070.0295

Bhagavatula, S., Elfring, T., van Tilburg, A., & van de Bunt, G. G. (2010). How social and human capital influence opportunity recognition and resource mobilization in India's handloom industry. *Journal of Business Venturing*, *25*(3), 245–260. https://doi.org/10.1016/j.jbusvent.2008.10.006

Bird, B. (1988). Implementing Entrepreneurial Ideas: The Case for Intention. *Academy of Management Review*, *13*(3), 442–453. https://doi.org/10.5465/amr.1988.4306970

Blind, K., Pohlisch, J., & Zi, A. (2018). Publishing, patenting, and standardization: Motives and barriers of scientists. *Research Policy*, *47*(7), 1185–1197. https://doi.org/10.1016/j.respol.2018.03.011

BMBF (Ed.). (2014). Bundesbericht Forschung und Innovation. *Berlin*, Bundesministerium für Bildung und Forschung (BMBF).

Boardman, C., & Ponomariov, B. L. (2009). University researchers working with private companies. *Technovation*, *29*(2), 142–153. https://doi.org/10.1016/j.technovation.2008.03.008

Bonaccorsi, A., Colombo, M. G., Guerini, M., & Rossi-Lamastra, C. (2014). The impact of local and external university knowledge on the creation of knowledge-intensive firms: Evidence from the Italian case. *Small Business Economics*, *43*(2), 261–287. https://doi.org/10.1007/s11187-013-9536-2

Bornmann, L. (2013). What is societal impact of research and how can it be assessed? A literature survey. *Journal of the American Society for Information Science and Technology*, *64*(2), 217–233. https://doi.org/10.1002/asi.22803

Bozeman, B., & Corley, E. (2004). Scientists' collaboration strategies: implications for scientific and technical human capital. *Research Policy*, *33*(4), 599–616. https://doi.org/10.1016/j.respol.2004.01.008

Bozeman, B., Rimes, H., & Youtie, J. (2015). The evolving state-of-the-art in technology transfer research: Revisiting the contingent effectiveness model. *Research Policy*, *44*(1), 34–49. https://doi.org/10.1016/j.respol.2014.06.008

Bradley, S. R., Hayter, C. S., & Link, A. N. (2013). Models and Methods of University Technology Transfer. *Foundations and Trends® in Entrepreneurship*, *9*(6), 571–650. https://doi.org/10.1561/0300000048

Broström, A. (2019). Academic breeding grounds: Home department conditions and early career performance of academic researchers. *Research Policy*, *48*(7), 1647–1665. https://doi.org/10.1016/j.respol.2019.03.009

Callaert, J., Landoni, P., van Looy, B., & Verganti, R. (2015). Scientific yield from collaboration with industry: The relevance of researchers' strategic approaches. *Research Policy*, *44*(4), 990–998. https://doi.org/10.1016/j.respol.2015.02.003

Cantner, U., Doerr, P., Goethner, M., Huegel, M., & Kalthaus, M. (2021). A procedural perspective on academic spin-off creation: The changing relevance of academic and commercial logics. *Jena Economic Research Papers*, *2021-020*, 1–55.

Cantner, U., Kalthaus, M., & Yarullina, I. (2022). Outcomes of Science-Industry Collaboration: Factors and Interdependencies. *Jena Economic Research Papers*, (2022-003), 1–40.

Civera, A., Meoli, M., & Vismara, S. (2020). Engagement of academics in university technology transfer: Opportunity and necessity academic entrepreneurship. *European Economic Review*, *123*, 103376. https://doi.org/10.1016/j.euroecorev.2020.103376

Cliff, J. E., Jennings, P. D., & Greenwood, R. (2006). New to the game and questioning the rules: The experiences and beliefs of founders who start imitative versus innovative firms. *Journal of Business Venturing*, *21*(5), 633–663. https://doi.org/10.1016/j.jbusvent.2005.02.010

Colyvas, J. A. (2007). From divergent meanings to common practices: The early institutionalization of technology transfer in the life sciences at Stanford University. *Research Policy*, *36*(4), 456–476. https://doi.org/10.1016/j.respol.2007.02.019

Corner, P. D., & Ho, M. (2010). How Opportunities Develop in Social Entrepreneurship. *Entrepreneurship Theory and Practice*, *34*(4), 635–659. https://doi.org/10.1111/j.1540-6520.2010.00382.x

Criaco, G., Minola, T., Migliorini, P., & Serarols-Tarrés, C. (2014). "To have and have not": Founders' human capital and university start-up survival. *The Journal of Technology Transfer*, *39*(4), 567–593. https://doi.org/10.1007/s10961-013-9312-0

Czarnitzki, D., Hussinger, K., & Schneider, C. (2011). Commercializing academic research: the quality of faculty patenting. *Industrial and Corporate Change*, *20*(5), 1403–1437. https://doi.org/10.1093/icc/dtr034

Dasgupta, P., & David, P. A. (1994). Toward a new economics of science. *Research Policy*, *23*(5), 487–521. https://doi.org/10.1016/0048-7333(94)01002-1

David, P. A., Mowery, D., & Steinmueller, W. E. (1992). Analysing The Economic Payoffs From Basic Research. *Economics of Innovation and New Technology*, *2*(1), 73–90. https://doi.org/10.1080/10438599200000006

Davidsson, P., & Honig, B. (2003). The role of social and human capital among nascent entrepreneurs. *Journal of Business Venturing*, *18*(3), 301–331. https://doi.org/10.1016/S0883-9026(02)00097-6

de Fuentes, C., & Dutrénit, G. (2012). Best channels of academia–industry interaction for long-term benefit. *Research Policy*, *41*(9), 1666–1682. https://doi.org/10.1016/j.respol.2012.03.026

de Grande, H., de Boyser, K., Vandevelde, K., & Van Rossem, R. (2014). From Academia to Industry: Are Doctorate Holders Ready? *Journal of the Knowledge Economy*, *5*(3), 538–561. https://doi.org/10.1007/s13132-014-0192-9

D'Este, P., & Patel, P. (2007). University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry? *Research Policy*, *36*(9), 1295–1313. https://doi.org/10.1016/j.respol.2007.05.002

D'Este, P., Guy, F., & Iammarino, S. (2012a). Shaping the formation of university–industry research collaborations: what type of proximity does really matter? *Journal of Economic Geography*, *13*(4), 1–22. https://doi.org/10.1093/jeg/lbs010

D'Este, P., Llopis, O., Rentocchini, F., & Yegros, A. (2019). The relationship between interdisciplinarity and distinct modes of university-industry interaction. *Research Policy*, *48*(9), 103799. https://doi.org/10.1016/j.respol.2019.05.008

D'Este, P., Mahdi, S., Neely, A., & Rentocchini, F. (2012b). Inventors and entrepreneurs in academia: What types of skills and experience matter? *Technovation*, *32*(5), 293–303. https://doi.org/10.1016/j.technovation.2011.12.005

Dietz, J. S., & Bozeman, B. (2005). Academic careers, patents, and productivity: industry experience as scientific and technical human capital. *Research Policy*, *34*(3), 349–367. https://doi.org/10.1016/j.respol.2005.01.008

Ding, W., & Choi, E. (2011). Divergent paths to commercial science: A comparison of scientists' founding and advising activities. *Research Policy*, *40*(1), 69–80. https://doi.org/10.1016/j.respol.2010.09.011

Dolmans, S. A. M., Walrave, B., Read, S., & van Stijn, N. (2022). Knowledge transfer to industry: how academic researchers learn to become boundary spanners during academic engagement. *The Journal of Technology Transfer*, *47*, 1422–1450. https://doi.org/10.1007/s10961-021-09882-1

Duchek, S. (2013). Capturing Absorptive Capacity: A Critical Review and Future Prospects. *Schmalenbach Business Review*, *65*(3), 312–329. https://doi.org/10.1007/BF03396860

Etzkowitz, H. (1998). The norms of entrepreneurial science: cognitive effects of the new university–industry linkages. *Research Policy*, *27*(8), 823–833. https://doi.org/10.1016/S0048-7333(98)00093-6

Etzkowitz, H., Webster, A., Gebhardt, C., & Terra, B. R. C. (2000). The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm. *Research Policy*, *29*(2), 313–330. https://doi.org/10.1016/S0048-7333(99)00069-4

Fabiano, G., Marcellusi, A., & Favato, G. (2020). Channels and processes of knowledge transfer: How does knowledge move between university and industry? *Science and Public Policy*, *47*(2), 256–270. https://doi.org/10.1093/scipol/scaa002

Fini, R., Rasmussen, E., Siegel, D., & Wiklund, J. (2018). Rethinking the Commercialization of Public Science: From Entrepreneurial Outcomes to Societal Impacts. *Academy of Management Perspectives*, *32*(1), 4–20. https://doi.org/10.5465/amp.2017.0206

Florida, R. (1999). Engine or lnfrastructure? The Univeraity Role in Economic Development (R. F. Lewis, M. Branscomb, & F. Kodama, Eds.). In R. F. Lewis, M. Branscomb, & F. Kodama (Eds.), *Industrializing knowledge: university-industry linkages in Japan and the United States*. Cambridge.

Forlani, D., & Mullins, J. W. (2000). Perceived risks and choices in entrepreneurs' new venture decisions. *Journal of Business Venturing*, *15*(4), 305–322. https://doi.org/10.1016/S0883-9026(98)00017-2

Fritsch, M., & Krabel, S. (2012). Ready to leave the ivory tower?: Academic scientists' appeal to work in the private sector. *The Journal of Technology Transfer*, *37*(3), 271–296. https://doi.org/10.1007/s10961-010-9174-7

Garcia, R., Araújo, V., Mascarini, S., Santos, E. G., & Costa, A. R. (2020). How long-term university-industry collaboration shapes the academic productivity of research groups. *Innovation*, *22*(1), 56–70. https://doi.org/10.1080/14479338.2019.1632711

George, G., Howard-Grenville, J., Joshi, A., & Tihanyi, L. (2016a). Understanding and Tackling Societal Grand Challenges through Management Research. *Academy of Management Journal*, *59*(6), 1880–1895. https://doi.org/10.5465/amj.2016.4007

George, N. M., Parida, V., Lahti, T., & Wincent, J. (2016b). A systematic literature review of entrepreneurial opportunity recognition: insights on influencing factors. *International Entrepreneurship and Management Journal*, *12*(2), 309–350. https://doi.org/10.1007/s11365-014-0347-y

Gerbin, A., & Drnovsek, M. (2020). Knowledge-sharing restrictions in the life sciences: personal and context-specific factors in academia–industry knowledge transfer. *Journal of Knowledge Management*, *24*(7), 1533–1557. https://doi.org/10.1108/JKM-11-2019-0651

Geuna, A., & Nesta, L. J. (2006). University patenting and its effects on academic research: The emerging European evidence. *Research Policy*, *35*(6), 790–807. https://doi.org/10.1016/j.respol.2006.04.005

Gibson, D. E. (2004). Role models in career development: New directions for theory and research. *Journal of Vocational Behavior*, *65*(1), 134–156. https://doi.org/10.1016/S0001-8791(03)00051-4

Giuliani, E., Morrison, A., Pietrobelli, C., & Rabellotti, R. (2010). Who are the researchers that are collaborating with industry? An analysis of the wine sectors in Chile, South Africa and Italy. *Research Policy*, *39*(6), 748–761. https://doi.org/10.1016/j.respol.2010.03.007

Giuri, P., Munari, F., Scandura, A., & Toschi, L. (2019). The strategic orientation of universities in knowledge transfer activities. *Technological Forecasting and Social Change*, *138*, 261–278. https://doi.org/10.1016/j.techfore.2018.09.030

Godin, B. (2006). The Linear Model of Innovation: The Historical Construction of an Analytic Framework. *Science, Technology, & Human Values*, *31*(6), 639–667. https://doi.org/10.1177/0162243906291865

Goethner, M., Obschonka, M., Silbereisen, R. K., & Cantner, U. (2011). Foundations of academic entrepreneurship: A path model for the prediction of scientists' academic entrepreneurial intentions. *DIME Final Conference*, 1–36.

Goethner, M., Obschonka, M., Silbereisen, R. K., & Cantner, U. (2012). Scientists' transition to academic entrepreneurship: Economic and psychological determinants. *Journal of Economic Psychology*, *33*(3), 628–641. https://doi.org/10.1016/j.joep.2011.12.002

Göktepe-Hulten, D., & Mahagaonkar, P. (2010). Inventing and patenting activities of scientists: in the expectation of money or reputation? *The Journal of Technology Transfer*, *35*(4), 401–423. https://doi.org/10.1007/s10961-009-9126-2

González-López, M. J., Pérez-López, M. C., & Rodríguez-Ariza, L. (2021). From potential to early nascent entrepreneurship: the role of entrepreneurial competencies. *International Entrepreneurship and Management Journal*, *17*(3), 1387–1417. https://doi.org/10.1007/s11365-020-00658-x

Graham, I. D., Logan, J., Harrison, M. B., Straus, S. E., Tetroe, J., Caswell, W., & Robinson, N. (2006). Lost in Knowledge Translation: Time for a Map? *The Journal of continuing education in the health professions*, *26*(1), 16557505, 13–24. https://doi.org/10.1002/chp.47

Greven, A., Strese, S., & Brettel, M. (2020). Determining scientists' academic engagement: perceptions of academic chairs' entrepreneurial orientation and network capabilities. *The Journal of Technology Transfer*, *45*(5), 1376–1404. https://doi.org/10.1007/s10961-019-09750-z

Grimpe, C., & Hussinger, K. (2013). Formal and Informal Knowledge and Technology Transfer from Academia to Industry: Complementarity Effects and Innovation Performance. *Industry & Innovation*, *20*(8), 683–700. https://doi.org/10.1080/13662716.2013.856620

Gruber, M., MacMillan, I. C., & Thompson, J. D. (2013). Escaping the Prior Knowledge Corridor: What Shapes the Number and Variety of Market Opportunities Identified Before Market Entry of Technology Start-ups? *Organization Science*, *24*(1), 280–300. https://doi.org/10.1287/orsc.1110.0721

Guerrero, M., & Urbano, D. (2012). The development of an entrepreneurial university. *The Journal of Technology Transfer*, *37*(1), 43–74. https://doi.org/10.1007/s10961-010-9171-x

Gulbrandsen, M., & Smeby, J.-C. (2005). Industry funding and university professors' research performance. *Research Policy*, *34*(6), 932–950. https://doi.org/10.1016/j.respol.2005.05.004

Gulbrandsen, M., & Thune, T. (2017). The effects of non-academic work experience on external interaction and research performance. *The Journal of Technology Transfer*, *42*(4), 795–813. https://doi.org/10.1007/s10961-017-9556-1

Gurdon, M. A., & Samsom, K. J. (2010). A longitudinal study of success and failure among scientist-started ventures. *Technovation*, *30*(3), 207–214. https://doi.org/10.1016/j.technovation.2009.10.004

Haeussler, C., & Colyvas, J. A. (2011). Breaking the Ivory Tower: Academic Entrepreneurship in the Life Sciences in UK and Germany. *Research Policy*, *40*(1), 41–54. https://doi.org/10.1016/j.respol.2010.09.012

Hayter, C. S. (2016). A trajectory of early-stage spinoff success: the role of knowledge intermediaries within an entrepreneurial university ecosystem. *Small Business Economics*, *47*(3), 633–656. https://doi.org/10.1007/s11187-016-9756-3

Hayter, C. S., Rasmussen, E., & Rooksby, J. H. (2020). Beyond formal university technology transfer: innovative pathways for knowledge exchange. *The Journal of Technology Transfer*, *45*(1), 1–8. https://doi.org/10.1007/s10961-018-9677-1

Heckman, J. J. (1979). Sample Selection Bias as a Specification Error. *Econometrica*, *47*(1), 153–161. https://doi.org/10.2307/1912352

Hmieleski, K. M., & Powell, E. E. (2018). The Psychological Foundations of University Science Commercialization: A Review of the Literature and Directions for Future Research. *Academy of Management Perspectives*, *32*(1), 43–77. https://doi.org/10.5465/amp.2016.0139

Horner, S., Jayawarna, D., Giordano, B., & Jones, O. (2019). Strategic choice in universities: Managerial agency and effective technology transfer. *Research Policy*. https://doi.org/10.1016/j.respol.2019.01.015

Horta, H., Meoli, M., & Vismara, S. (2016). Skilled unemployment and the creation of academic spin-offs: a recession-push hypothesis. *The Journal of Technology Transfer*, *41*(4), 798–817. https://doi.org/10.1007/s10961-015-9405-z

Hossinger, S. M., Chen, X., & Werner, A. (2020). Drivers, barriers and success factors of academic spin-offs: a systematic literature review. *Management Review Quarterly*, *70*(1), 97–134. https://doi.org/10.1007/s11301-019-00161-w

Hossinger, S., Block, J., Chen, X., & Werner, A. (2021). Venture creation patterns in academic entrepreneurship: the role of founder motivations. *The Journal of Technology Transfer*. https://doi.org/10.1007/s10961-021-09904-y

Hsieh, C., Nickerson, J. A., & Zenger, T. R. (2007). Opportunity Discovery, Problem Solving and a Theory of the Entrepreneurial Firm. *Journal of Management Studies*, *44*(7), 1255–1277. https://doi.org/10.1111/j.1467-6486.2007.00725.x

Huyghe, A., & Knockaert, M. (2015). The influence of organizational culture and climate on entrepreneurial intentions among research scientists. *The Journal of Technology Transfer*, *40*(1), 138–160. https://doi.org/10.1007/s10961-014-9333-3

Iorio, R., Labory, S., & Rentocchini, F. (2017). The importance of pro-social behaviour for the breadth and depth of knowledge transfer activities: An analysis of Italian academic scientists. *Research Policy*, *46*(2), 497–509. https://doi.org/10.1016/j.respol.2016.12.003

Jacobson, N., Butterill, D., & Goering, P. (2004). Organizational Factors that Influence University-Based Researchers' Engagement in Knowledge Transfer Activities. *Science Communication*, *25*(3), 246–259. https://doi.org/10.1177/1075547003262038

Kalar, B., & Antoncic, B. (2015). The entrepreneurial university, academic activities and technology and knowledge transfer in four European countries. *Technovation*, *36-37*, 1–11. https://doi.org/10.1016/j.technovation.2014.11.002

Karnani, F. (2012). The university's unknown knowledge: tacit knowledge, technology transfer and university spin-offs findings from an empirical study based on the theory of knowledge. *The Journal of Technology Transfer*, *38*(3), 235–250. https://doi.org/10.1007/s10961-012-9251-1

Krabel, S., & Mueller, P. (2009). What drives scientists to start their own company? *Research Policy*, *38*(6), 947–956. https://doi.org/10.1016/j.respol.2009.02.005

Lacetera, N. (2009). Academic entrepreneurship. *Managerial and Decision Economics*, *30*(7), 443–464. https://doi.org/10.1002/mde.1461

Lam, A. (2010). From 'Ivory Tower Traditionalists' to 'Entrepreneurial Scientists'? *Social Studies of Science*, *40*(2), 307–340. https://doi.org/10.1177/0306312709349963

Lam, A. (2011). What motivates academic scientists to engage in research commercialization: 'Gold', 'ribbon' or 'puzzle'? *Research Policy*, *40*(10), 1354–1368. https://doi.org/10.1016/j.respol.2011.09.002

Landry, R., Amara, N., & Ouimet, M. (2007). Determinants of knowledge transfer: evidence from Canadian university researchers in natural sciences and engineering. *The Journal of Technology Transfer*, *32*(6), 561–592. https://doi.org/10.1007/s10961-006-0017-5

Landry, R., Saïhi, M., Amara, N., & Ouimet, M. (2010). Evidence on how academics manage their portfolio of knowledge transfer activities. *Research Policy*, *39*(10), 1387–1403. https://doi.org/10.1016/j.respol.2010.08.003

Lee, Y. S. (2000). The sustainability of university-industry research collaboration: An empirical assessment. *The Journal of Technology Transfer*, *25*(2), 111–133.

Leitner, K.-H., Bergner, S., & Rybnicek, R. (2021). The role of heads of departments in the commercialization of university research. *Journal of Business Economics*, *91*(3), 353–378. https://doi.org/10.1007/s11573-020-01003-y

Llopis, O., Sánchez-Barrioluengo, M., Olmos-Peñuela, J., & Castro-Martínez, E. (2018). Scientists' engagement in knowledge transfer and exchange: individual factors, variety of mechanisms and users. *Science and Public Policy*, *45*(6), 790–803. https://doi.org/10.1093/scipol/scy020

Louis, K. S., Blumenthal, D., Gluck, M. E., & Stoto, M. A. (1989). Entrepreneurs in Academe: An Exploration of Behaviors among Life Scientists. *Administrative Science Quarterly*, *34*(1), 110–131. https://doi.org/10.2307/2392988

Maresova, P., Stemberkova, R., & Fadeyi, O. (2019). Models, Processes, and Roles of Universities in Technology Transfer Management: A Systematic Review. *Administrative Sciences*, *9*(3), 67. https://doi.org/10.3390/admsci9030067

Marquis, C., & Tilcsik, A. (2013). Imprinting: Toward a Multilevel Theory. *Academy of Management Annals*, *7*(1), 195–245. https://doi.org/10.1080/19416520.2013.766076

Martín-Martín, A., Thelwall, M., Orduna-Malea, E., & Delgado López-Cózar, E. (2021). Google Scholar, Microsoft Academic, Scopus, Dimensions, Web of Science, and OpenCitations' COCI: a multidisciplinary comparison of coverage via citations. *Scientometrics*, *126*(1), 871–906. https://doi.org/10.1007/s11192-020-03690-4

Mejri, K., & Umemoto, K. (2010). Small- and medium-sized enterprise internationalization: Towards the knowledge-based model. *Journal of International Entrepreneurship*, *8*(2), 156–167. https://doi.org/10.1007/s10843-010-0058-6

Merton, R. K. (1968). *Social theory and social structure* (Enlarged edition). New York, NY, Free Press.

Merton, R. K. (1973). *The sociology of science Theoretical and empirical investigations: Theoretical and empirical investigations*. Chicago, The University of Chicago Press.

Miranda, A., & Rabe-Hesketh, S. (2006). Maximum Likelihood Estimation of Endogenous Switching and Sample Selection Models for Binary, Ordinal, and Count Variables. *The Stata Journal: Promoting communications on statistics and Stata*, *6*(3), 285–308. https://doi.org/10.1177/1536867X0600600301

Mosey, S., & Wright, M. (2007). From Human Capital to Social Capital: A Longitudinal Study of Technology-Based Academic Entrepreneurs. *Entrepreneurship Theory and Practice*, *31*(6), 909–935. https://doi.org/10.1111/j.1540-6520.2007.00203.x

Moutinho, P. S. F., Fontes, M., & Godinho, M. M. (2007). Do individual factors matter? A survey of scientists' patenting in Portuguese public research organisations. *Scientometrics*, *70*(2), 355–377. https://doi.org/10.1007/s11192-007-0207-4

Müller, K. (2010). Academic spin-off's transfer speed—Analyzing the time from leaving university to venture. *Research Policy*, *39*(2), 189–199. https://doi.org/10.1016/j.respol.2009.12.001

Murray, F. (2010). The Oncomouse That Roared: Hybrid Exchange Strategies as a Source of Distinction at the Boundary of Overlapping Institutions. *American Journal of Sociology*, *116*(2), 341–388. https://doi.org/10.1086/653599

Murray, F., & Stern, S. (2007). Do formal intellectual property rights hinder the free flow of scientific knowledge? An empirical test of the anti-commons hypothesis. *Journal of Economic Behavior & Organization*, *63*(4), 648–687. https://doi.org/10.1016/j.jebo.2006.05.017

Muscio, A., Quaglione, D., & Ramaciotti, L. (2016). The effects of university rules on spinoff creation: The case of academia in Italy. *Research Policy*, *45*(7), 1386–1396. https://doi.org/10.1016/j.respol.2016.04.011

Ndonzuau, F. N., Pirnay, F., & Surlemont, B. (2002). A stage model of academic spin-off creation. *Technovation*, *22*(5), 281–289. https://doi.org/10.1016/S0166-4972(01)00019-0

Nemet, G. F. (2009). Demand-pull, technology-push, and government-led incentives for non-incremental technical change. *Research Policy*, *38*(5), 700–709. https://doi.org/10.1016/j.respol.2009.01.004

Neves, M., & Franco, M. (2018). Academic spin–off creation: barriers and how to overcome them. *R&D Management*, *48*(5), 505–518. https://doi.org/10.1111/radm.12231

Neves, S., & Brito, C. (2020). Academic entrepreneurship intentions: a systematic literature review. *Journal of Management Development*, *39*(5), 645–704. https://doi.org/10.1108/JMD-11-2019-0451

Nicolaou, N., & Birley, S. (2003). Academic networks in a trichotomous categorisation of university spinouts. *Journal of Business Venturing*, *18*(3), 333–359. https://doi.org/10.1016/S0883-9026(02)00118-0

OECD (Ed.). (2013). Benchmarking knowledge transfer and commercialisation, In *Commercialising Public Research: New Trends and Strategies*. OECD Publishing.

Olmos-Peñuela, J., Castro-Martínez, E., & D'Este, P. (2014). Knowledge transfer activities in social sciences and humanities: Explaining the interactions of research groups with non-academic agents. *Research Policy*, *43*(4), 696–706. https://doi.org/10.1016/j.respol.2013.12.004

Owen-Smith, J., & Powell, W. W. (2001). To Patent or Not: Faculty Decisions and Institutional Success at Technology Transfer. *The Journal of Technology Transfer*, *26*(1), 99–114. https://doi.org/10.1023/A:1007892413701

Ozgen, E., & Baron, R. A. (2007). Social sources of information in opportunity recognition: Effects of mentors, industry networks, and professional forums. *Journal of Business Venturing*, *22*(2), 174–192. https://doi.org/10.1016/j.jbusvent.2005.12.001

Perkmann, M., & Walsh, K. (2009). The two faces of collaboration: impacts of university-industry relations on public research. *Industrial and Corporate Change*, *18*(6), 1033–1065. https://doi.org/10.1093/icc/dtp015

Perkmann, M., King, Z., & Pavelin, S. (2011). Engaging excellence? Effects of faculty quality on university engagement with industry. *Research Policy*, *40*(4), 539–552. https://doi.org/10.1016/j.respol.2011.01.007

Perkmann, M., McKelvey, M., & Phillips, N. (2019). Protecting Scientists from Gordon Gekko: How Organizations Use Hybrid Spaces to Engage with Multiple Institutional Logics. *Organization Science*, *30*(2), 298–318. https://doi.org/10.1287/orsc.2018.1228

Perkmann, M., Salandra, R., Tartari, V., McKelvey, M., & Hughes, A. (2021). Academic engagement: A review of the literature 2011-2019. *Research Policy*, *50*(1), 1–20. https://doi.org/10.1016/j.respol.2020.104114

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A., & Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy*, *42*(2), 423–442. https://doi.org/10.1016/j.respol.2012.09.007

Philbin, S. (2008). Process model for university–industry research collaboration. *European Journal of Innovation Management*, *11*(4), 488–521. https://doi.org/10.1108/14601060810911138

Pilegaard, M., Moroz, P. W., & Neergaard, H. (2010). An Auto-Ethnographic Perspective on Academic Entrepreneurship: Implications for Research in the Social Sciences and Humanities. *Academy of Management Perspectives*, *24*(1), 46–61. https://doi.org/10.5465/amp.24.1.46

Pirnay, F., Surlemont, B., & Nlemvo, F. (2003). Toward a Typology of University Spin-offs. *Small Business Economics*, *21*(4), 355–369. https://doi.org/10.1023/A:1026167105153

Ponomariov, B., & Boardman, C. (2012). Organizational Behavior and Human Resources Management for Public to Private Knowledge Transfer: An Analytic Review of the Literature (OECD Science, Technology and Industry Working Papers, Ed.). https://doi.org/10.1787/5k9d4gt7mdbp-en

Ramos-Rodríguez, A.-R., Medina-Garrido, J.-A., Lorenzo-Gómez, J.-D., & Ruiz-Navarro, J. (2010). What you know or who you know? The role of intellectual and social capital in opportunity recognition. *International Small Business Journal: Researching Entrepreneurship*, *28*(6), 566–582. https://doi.org/10.1177/0266242610369753

Rappert, B., Webster, A., & Charles, D. (1999). Making sense of diversity and reluctance: academic–industrial relations and intellectual property. *Research Policy*, *28*(8), 873–890. https://doi.org/10.1016/S0048-7333(99)00028-1

Rodeiro-Pazos, D., Fernández-López, S., Rodríguez-Gulías, M. J., & Dios-Vicente, A. (2021). Size and survival: An analysis of the university spin-offs. *Technological Forecasting and Social Change*, *171*, 120953. https://doi.org/10.1016/j.techfore.2021.120953

Roodman, D. (2011). Fitting Fully Observed Recursive Mixed-process Models with cmp. *The Stata Journal: Promoting communications on statistics and Stata*, *11*(2), 159–206. https://doi.org/10.1177/1536867X1101100202

Rothaermel, F. T., & Thursby, M. (2005). Incubator firm failure or graduation? *Research Policy*, *34*(7), 1076–1090. https://doi.org/10.1016/j.respol.2005.05.012

Salter, A., Ter Wal, A. L. J., Criscuolo, P., & Alexy, O. (2015). Open for Ideation: Individual–Level Openness and Idea Generation in R&D. *Journal of Product Innovation Management*, *32*(4), 488–504. https://doi.org/10.1111/jpim.12214

Sauermann, H., & Stephan, P. E. (2013). Conflicting logics? A multidimensional view of industrial and academic science. *Organization Science*, *24*(3), 889–909. https://doi.org/10.1287/orsc.1120.0769

Schaeffer, V., Öcalan-Özel, S., & Pénin, J. (2020). The complementarities between formal and informal channels of university–industry knowledge transfer: a longitudinal approach. *The Journal of Technology Transfer*, *45*(1), 31–55. https://doi.org/10.1007/s10961-018-9674-4

Scherer, R. F., Adams, J. S., Carley, S. S., & Wiebe, F. A. (1989). Role Model Performance Effects on Development of Entrepreneurial Career Preference. *Entrepreneurship Theory and Practice*, *13*(3), 53–72. https://doi.org/10.1177/104225878901300306

Senior, M. (2020). Europe's biotech renaissance. *Nature biotechnology*, *38*(4), 408–415. https://doi.org/10.1038/s41587-020-0483-6

Shane, S. (2000). Prior Knowledge and the Discovery of Entrepreneurial Opportunities. *Organization Science*, *11*(4), 448–469. https://doi.org/10.1287/orsc.11.4.448.14602

Shane, S. (2001). Technological Opportunities and New Firm Creation. *Management Science*, *47*(2), 205–220. https://doi.org/10.1287/mnsc.47.2.205.9837

Shane, S. A. (2003). *A general theory of entrepreneurship The individual-opportunity nexus: The individual-opportunity nexus*. Cheltenham, U.K., Edward Elgar Publishing. https://doi.org/10.4337/9781781007990

Shane, S., & Venkataraman, S. (2000). The Promise of Enterpreneurship as a Field of Research. *The Academy of Management Review*, *25*(1), 217–226. https://doi.org/10.2307/259271

Shepherd, D. A., & DeTienne, D. R. (2005). Prior Knowledge, Potential Financial Reward, and Opportunity Identification. *Entrepreneurship Theory and Practice*, *29*(1), 91–112. https://doi.org/10.1111/j.1540-6520.2005.00071.x

Siegel, D. S., Waldman, D. A., Atwater, L. E., & Link, A. N. (2003). Commercial knowledge transfers from universities to firms: improving the effectiveness of university–industry collaboration. *The Journal of High Technology Management Research*, *14*(1), 111–133. https://doi.org/10.1016/S1047-8310(03)00007-5

Siegel, D. S., Waldman, D. A., Atwater, L. E., & Link, A. N. (2004). Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies. *Journal of Engineering and Technology Management*, *21*(2-1), 115–142. https://doi.org/10.1016/j.jengtecman.2003.12.006

Snihur, Y., Reiche, B. S., & Quintane, E. (2017). Sustaining Actor Engagement During the Opportunity Development Process. *Strategic Entrepreneurship Journal*, *11*(1), 1–17. https://doi.org/10.1002/sej.1233

SOEP-IS Group. (2014). *SOEP-IS 2014 – Fragebogen für die SOEP-Innovations-Stichprobe Fragebogen für die SOEP-Innovations-Stichprobe: Fragebogen für die SOEP-Innovations-*

Stichprobe (Vol. 519). Berlin, Germany, The German Socio-Economic Panel study at DIW Berlin.

Sousa-Ginel, E., Franco-Leal, N., & Camelo-Ordaz, C. (2021). Knowledge conversion capability and networks as drivers of innovation in Academic Spin-Offs. *Journal of Engineering and Technology Management*, *59*, 101615. https://doi.org/10.1016/j.jengtecman.2021.101615

Statistisches Bundesamt. (2020). *Bildung und Kultur Personal an Hochschulen: Personal an Hochschulen*. Statistisches Bundesamt.

Stephan, P. E. (1996). The economics of science. *Journal of economic literature*, *34*(3), 1199–1235.

Stokes, D. (1997). *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, DC, The Brookings Institution.

Sue, V. M., & Ritter, L. A. (2007). *Conducting online surveys*. Los Angeles, Sage.

Tartari, V., & Breschi, S. (2012). Set them free: scientists' evaluations of the benefits and costs of university-industry research collaboration. *Industrial and Corporate Change*, *21*(5), 1117–1147. https://doi.org/10.1093/icc/dts004

Tartari, V., Perkmann, M., & Salter, A. (2014). In good company: The influence of peers on industry engagement by academic scientists. *Research Policy*, *43*(7), 1189–1203. https://doi.org/10.1016/j.respol.2014.02.003

Tartari, V., & Salter, A. (2015). The engagement gap: Exploring gender differences in University – Industry collaboration activities. *Research Policy*, *44*(6), 1176–1191. https://doi.org/10.1016/j.respol.2015.01.014

Tartari, V., Salter, A., & D'Este, P. (2012). Crossing the Rubicon: exploring the factors that shape academics' perceptions of the barriers to working with industry. *Cambridge journal of economics*, *36*(3), 655–677. https://doi.org/10.1093/cje/bes007

Todorovic, Z. W., McNaughton, R. B., & Guild, P. (2011). ENTRE-U: An entrepreneurial orientation scale for universities. *Technovation*, *31*(2-3), 128–137. https://doi.org/10.1016/j.technovation.2010.10.009

van Gelderen, M., Thurik, R., & Bosma, N. (2005). Success and Risk Factors in the Pre-Startup Phase. *Small Business Economics*, *24*(4), 365–380. https://doi.org/10.1007/s11187-004-6994-6

van Looy, B., Ranga, M., Callaert, J., Debackere, K., & Zimmermann, E. (2004). Combining entrepreneurial and scientific performance in academia: towards a compounded and reciprocal Matthew-effect? *Research Policy*, *33*(3), 425–441. https://doi.org/10.1016/j.respol.2003.09.004

Veugelers, R., & Wang, J. (2019). Scientific novelty and technological impact. *Research Policy*, *48*(6), 1362–1372. https://doi.org/10.1016/j.respol.2019.01.019

Vismara, S., & Meoli, M. (2016). Poor opportunities in the academic labor market as a cause of spin-offs (P. Phan, Ed.). In P. Phan (Ed.), *Academic Entrepreneurship*. Edward Elgar Publishing. https://doi.org/10.4337/9781785363443.00009

Vohora, A., Wright, M., & Lockett, A. (2004). Critical junctures in the development of university high-tech spinout companies. *Research Policy*, *33*(1), 147–175. https://doi.org/10.1016/S0048-7333(03)00107-0

Walsh, V. (1984). Invention and innovation in the chemical industry: Demand-pull or discovery-push? *Research Policy*, *13*(4), 211–234. https://doi.org/10.1016/0048-7333(84)90015-5

Waltman, L., van Eck, N. J., van Leeuwen, T. N., & Visser, M. S. (2013). Some modifications to the SNIP journal impact indicator. *Journal of Informetrics*, *7*(2), 272–285. https://doi.org/10.1016/j.joi.2012.11.011

Wennberg, K., Wiklund, J., & Wright, M. (2011). The effectiveness of university knowledge spillovers: Performance differences between university spinoffs and corporate spinoffs. *Research Policy*, *40*(8), 1128–1143. https://doi.org/10.1016/j.respol.2011.05.014

Wilde, J. (2000). Identification of multiple equation probit models with endogenous dummy regressors. *Economics Letters*, *69*(3), 309–312. https://doi.org/10.1016/S0165-1765(00)00320-7

Wood, M. S. (2011). A process model of academic entrepreneurship. *Business Horizons*, *54*(2), 153–161. https://doi.org/10.1016/j.bushor.2010.11.004

Wu, Y., Welch, E. W., & Huang, W.-L. (2015). Commercialization of university inventions: Individual and institutional factors affecting licensing of university patents. *Technovation*, *36-37*, 12–25. https://doi.org/10.1016/j.technovation.2014.09.004

Xiao, T., Makhija, M., & Karim, S. (2022). A Knowledge Recombination Perspective of Innovation: Review and New Research Directions. *Journal of Management*, (48), 1724–1777. https://doi.org/10.1177/01492063211055982

Zahra, S. A., van de Velde, E., & Larrañeta, B. (2007). Knowledge conversion capability and the performance of corporate and university spin-offs. *Industrial and Corporate Change*, *16*(4), 569–608. https://doi.org/10.1093/icc/dtm018

Zhou, R., & Tang, P. (2020). The role of university Knowledge Transfer Offices: Not just commercialize research outputs! *Technovation*, *90-91*, 102100. https://doi.org/10.1016/j.technovation.2019.102100

Zucker, L. G., Darby, M. R., & Brewer, M. B. (1998). Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises. *The American Economic Review*, *88*(1), 290–306. http://www.jstor.org/stable/116831

Zuniga, P., & Correa, P. (2013). Technology transfer from public research organizations: concepts, markets, and institutional failures. *World Bank*.

IMPRESSUM
Jena Economic Research Papers
ISSN 1864-7057
Friedrich Schiller University Jena
Faculty of Economics and Business Administration
Carl-Zeiss-Str. 3
D-07743 Jena, Germany

Email: office.jerp@uni-jena.de
Editor: Silke Übelmesser
Website: www.wiwi.uni-jena.de/en/jerp