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Article

The Use of Faculty Inventor Social Capital to Facilitate University Technology Transfer: A Multiple Case Study Inquiry Using Qualitative Comparative Analysis

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Abstract

The current practices of the university technology transfer profession seem to reflect the belief that the chances for success are greatly improved when faculty inventors employ their social capital to facilitate the process. However, this notion has not been extensively investigated directly. There is a gap in the university technology transfer literature regarding our understanding of faculty inventor social capital in the context of the occurrence of technology transfer outcomes. The aim of this study was to understand whether the use of faculty inventor social capital is a causal condition for the occurrence of university technology transfer. This question was examined using a multiple case study approach and the qualitative comparative analysis (QCA) method. The data were generated by collecting information on 21 cases that occurred during or around calendar year 2019 in which a private sector organization considered whether to obtain and assimilate a technology that was created at a university in the United States of America. The results of the study suggest that the use of faculty inventor social capital is not a necessary, sufficient, or INUS condition for the occurrence of university technology transfer.

Keywords: faculty inventor; social capital; technology transfer; science policy; technology policy; qualitative comparative analysis

Journal of Economic Literature (JEL) classification codes: D21, D22, D23, D80, D91, L24, L29, O14, O31, O32, O33, O38, O39

Introduction

In the early years of the university technology transfer industry following the passage of the Bayh-Dole Act of 1980, the role of faculty inventors quickly emerged as a research focus for studies of university-industry technology transfer. Much of this research focused on characteristics of faculty inventors, factors that influence faculty engagement in patenting and the technology transfer process, and the impact of technology transfer public policy on academic research and knowledge creation (see Agrawal, 2001). Investigations of faculty social capital focused on the role of professional networks in technology transfer often with an emphasis on knowledge production and technology creation. Such investigations continue to this day as exemplified by Corvello et al. (2020) which demonstrated how research-focused digital social networking platforms contribute to knowledge creation and the development of researcher competencies.

Early technology transfer studies suggested that the research outputs of faculty inventors with social capital in the form of connections to industry tended to be successfully transferred to the private sector more often than the research outputs of faculty without such connections (see e.g.,Agrawal, 2001; Shane & Stuart, 2002; Zucker et al., 2002). Such studies led scholars to conclude

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that faculty inventors had an important role in the process of licensing the technologies they create (see Agrawal, 2001; Thursby & Thursby, 2004).

The current practices of the technology transfer profession seem to reflect the belief that the chances for success in technology transfer are greatly improved when the faculty inventors employ their social capital to facilitate the transfer. The websites of several university technology transfer offices (TTOs) communicate something like what the TTO for the University of California – Los Angeles posts on its frequently asked questions (FAQ) page about how licensees are found and how faculty can help:

Studies have shown that 70% of licensees were known to the inventors. Thus research and consulting relationships are often a valuable source for licensees and we strongly encourage you to let us know about your industry contacts… Your active involvement can dramatically improve the chances of finding a licensee.

Other university TTOs that have posted similar statements include those for Bowling Green State University, Duke University, North Carolina State University, Princeton University, Rowan University, and University of Texas Health Science Center at San Antonio.

On these websites, the 70% statistic is provided without citation of the studies that are referenced. But more importantly, the language clearly implies that in a significant majority of instances, the social capital of the faculty inventor is essential for the success of technology transfer efforts. However, there are several epistemological concerns associated with this belief and the studies on which it may be based.

Much of the research that probes the link between faculty social capital and university technology transfer outcomes is survey-based and interview-based descriptive research that relies on the ability of respondents to accurately report aggregate or average percentages associated with specific activities that occurred one or more years in the past (see e.g.,Thursby & Thursby, 2001; Thursby & Thursby, 2004). Additionally, survey responses are often subject to non-response bias. While human memory is biologically remarkable, it is largely a reconstructive process that is highly susceptible to distortion and error (see Roediger & Gallo, 2002). Finally, survey-based descriptive research also poses challenges for interpreting the results.

Case-based research studies have also been used to illustrate the importance of faculty inventors using their social capital to facilitate engagement with the eventual licensees of university technologies (see e.g., Al-Tabbaa & Ankrah, 2016; Martinelli et al., 2007; Secundo et al., 2019). This type of research is more suitable for theory development than theory testing. While it is perfectly reasonable for such case studies to hypothesize that faculty inventor social capital is a non-spurious causal factor for successfully licensing university technology, such hypotheses must be tested. However, it seems that theories postulating the importance of faculty inventors using their social capital to facilitate the successful transfer of university technologies have been accepted without such testing. Therefore, the aim of this study was to examine with scientific rigor, whether the use of social capital by faculty inventors is a causal factor for the occurrence of university technology transfer.

Literature Review

This section summarizes the literature related to the research aim. It first recaps the broader literature on social capital. It then outlines the literature about social capital in the context of university technology transfer. Finally, the literature related to the potential link between the active use of faculty inventor social capital and university technology transfer outcomes is discussed.

The Construct of Social Capital

Social capital is a sociological construct that refers to common values, mutual trust, and patterns of reciprocal exchange that act as a resource for members of a social network (Amarathunga, 2025; Edwards, 2011; Manning, 2017). Social capital has multiple dimensions and comes in various forms, some of which may be more useful for certain things while other forms are more useful for different

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things (Putnam, 2001). Scholars have offered several schemes for classifying social capital (see Bhandari & Yasunobu, 2009). One of the more popular classification schemes conceptualizes it as having three main forms – bridging, bonding, and linking (see Amarathunga, 2025; Edwards, 2011). Theorists hypothesize that bridging social capital is a causal factor for career and business success as well as other individual, organizational, and societal desired outcomes (see Edwards, 2011; Villalonga-Olives & Kawachi, 2015).

In the most popular social capital classification scheme, bonding social capital is conceptualized as mutual trust and reciprocal exchange among individuals within a close-knit social group (Edwards, 2011; Villalonga-Olives & Kawachi, 2015). This conceptualization is ambiguous because the term "close-knit" is ambiguous. Bridging social capital is conceptualized as mutual trust and reciprocal exchange between people from different social groups (see Ahmad et al., 2023; Edwards). As described in the literature, both bonding and bridging social capital can manifest as micro-level phenomena that act at the level of individuals as well as the meso- and macro-level phenomena. Woolcock (1998) proposed what has come to be called *linking social capital* as a third form, conceptualizing it as the social connections of individuals and communities with government and broader societal institutions such as non-governmental organizations (NGOs). Linking social capital is an inter-level phenomenon that acts at both the micro- and meso-level (see Agger & Jensen, 2015; Kyne & Aldrich, 2020). However, its conceptualization and operationalization in research studies tend to reify both the social capital construct and institutions.

There are several definitional and methodological criticisms of the social capital concept (see e.g., Edwards, 2011; Engbers et al., 2015; Villalonga-Olives & Kawachi, 2015). Two of the more fundamental criticisms are regarding the ambiguity of the concept and its operationalization. There is no agreement among scholars about the definition of social capital and many scholars develop their own meaning for the concept (see Claridge, 2018; Foley & Edwards, 1999; Haynes, 2009; Woolcock, 1998). Claridge (2018) argues that many scholars use the term *social capital* in their research "when it would be more appropriate to use a related term that has a more relevant meaning" (p. 2). Additionally, the accurate and consistent measurement of the concept has proven elusive (see Claridge, 2018; Engbers et al., 2015; Foley & Edwards, 1999; Haynes, 2009).

Social Capital in the Context of University Technology Transfer

The link between social capital and knowledge transfer is a relatively young stream of research (see Inkpen & Tsang, 2016). Much of it seems to be conducted at the meso- and macro-level. As described by Inkpen & Tsang, research tends to be guided by the following three main premises:

1. Intra-organizational social networks, formal inter-organizational networks, geographically close inter-organizational networks serve as conduits for knowledge transfer.
2. Social capital has a critical role in the function of networks as conduits for processing and moving knowledge.
3. There is at least one facilitating condition for each type of network and facet of social capital that supports knowledge transfer.

The terms "knowledge transfer" and "technology transfer" are sometimes used interchangeably in lay contexts. However, strictly speaking the two are not synonymous (see Gopalakrishnan & Santora, 2004; Ismail et al., 2018; Townes, 2022, 2025). Knowledge transfer is a broader concept and is more akin to organizational learning within the scientific paradigm for investigations about social capital and knowledge transfer. For this investigation, technology is broadly conceptualized as culturally influenced information that social actors use to pursue the objectives of their motivations, and which is embodied in such a manner to enable, hinder, or otherwise controls its access and use (Townes, 2022, 2024). Technology transfer is defined as the voluntary conveyance of technology from the possession of one social actor (e.g., universities and federal laboratories) to another social actor (e.g., private sector organizations) for the purpose of applying the technology in a setting in which it has not previously been applied (Townes).

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There is an extensive literature on social capital in the context of university technology transfer. However, it generally does not delve into the micro-level examination of the link between faculty social capital and technology transfer outcomes. Instead, research within this field tends to fall into the following streams:

1. The relationship between faculty social capital and faculty members' level of engagement in the technology transfer process (see e.g., Kalhor et al., 2020)
2. The role of social networks in collaborative endeavors between universities and private sector firms in specific industries (see e.g., Chakrabarti & Santoro, 2004)
3. The role of social capital in enabling university faculty to overcome obstacles to engaging in collaborations with industry (see e.g., Rossoni et al., 2023)
4. The effect of social capital on the entrepreneurial intentions of university faculty (see e.g., Agapova et al., 2020)

Much of the research on social capital in the context of university technology transfer is at the meso- and macro-level. The most often used methodologies and methods tend to be surveys, structural equation modeling (SEM), and regression analysis. Such approaches do not accommodate university technology transfer as a causally complex phenomenon. Qualitative methods such as in-depth interviews, case studies, and content analysis are also used and are likely employed for theory development. Relatively little research has explored faculty social capital at the micro-level and its potential influence on producing university technology transfer outcomes such as licenses of university-owned technologies to private sector firms. Moreover, there do not appear to be any studies that investigate university technology transfer as a sociological phenomenon subject to causal complexity in which faculty social capital is a potential causal factor.

Faculty Social Capital and University Technology Transfer Outcomes

There is little relevant literature that applies the concept of faculty inventor social capital to the study of university technology transfer outcomes. The literature that was identified examines social capital in the context of knowledge transfer as a predictor of a faculty member's tendency to engage in antecedent behaviors of technology transfer (see Al-Tabbaa & Ankrah, 2016; Kalar & Antoncic, 2016). Scholars and practitioners consider the presence or absence of social capital as an influential factor in inter-organizational processes of knowledge transfer at the meso-level (see e.g., Filieri & Alguezaui, 2014; Inkpen & Tsang, 2005; Inkpen & Tsang, 2016; Robertson et al., 2019). However, these studies tend to reify the organization construct and do not provide insight into the relationship between the social capital of university faculty inventors and the outcomes of efforts to transfer technologies created at universities.

Theoretically, faculty inventors can use their social capital to contribute to successful university technology transfer in several ways. For example, faculty inventors can use their personal and professional relationships to identify and solicit potential licensees. Alternatively, they can leverage such relationships to facilitate the formation and launch of university startups. In either case, faculty inventors are leveraging their social capital to facilitate the technology transfer process with the goal of producing an outcome of successfully conveying technology from the university to private sector organizations.

There have been studies that have broached the subject of faculty social capital and its potential influence university technology transfer outcomes. Jansen and Dillon (2000) appear to be among the earliest studies to investigate in any fashion the use of faculty inventor social capital to facilitate university technology transfer. They reported that leads provided by the faculty inventor accounted for 56% of technology licenses that were executed. However, it does not indicate what percentage of faculty inventor leads resulted in a license. The study also does not provide any indication of the amount or kind of social capital involved. For example, it does not differentiate between leads in which the faculty inventor had some level of personal or professional relationship with the licensee contact and leads in which the faculty inventor only had knowledge of the contact but did not have

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a real relationship with the licensee contact. Additionally, their survey-based study draws conclusions based on data from only six of the 261 research universities in existence at the time. Respondents provided data, primarily based on their memories of the events, regarding the source of leads for options and licenses for periods ranging from 2.5 to 13 years in the past.

Thursby and Thursby (2001) extended the work of Jansen and Dillon (2000) by approaching the question from the perspective of the licensees. They also employed a survey methodology. They reported that 77% of respondents indicated that personal contacts with university personnel was either important or extremely important. Although their survey question did not differentiate university personnel as either faculty inventors or TTO staff, Thursby and Thursby argue, without providing support, that "it is almost certainly the case that the personal contacts of industry R&D staff with university researchers are very important" (p. 292).

The conflation of these two studies appears to be the source of the 70% statistic often quoted by university technology transfer offices. Like a game of telephone in which the message that the final person in a chain receives is quite different from the original message communicated by the first person in the chain, the conclusions drawn from these studies have been significantly morphed and over-generalized as they have been communicated throughout the technology transfer profession. Both studies also make a normative argument by framing the technology marketing efforts of TTOs as relatively unimportant. Other studies with similar methodologies have reinforced this narrative (see Agrawal & Henderson, 2002; Colyvas et al., 2002; Jensen & Thursby, 2001; Thursby & Thursby, 2004).

Interpreting the results of these studies is difficult. For example, what exactly does "important" mean in the Thursby and Thursby (2001) study and others like it? Moreover, even if there is agreement about the meaning of the term, we cannot be entirely confident that respondents' memories are not distorting the "importance" of factors such as personal contacts since the they are reporting on past historical events that have occurred as many as 13 years prior. Also, what exactly is the definition of "personal contacts"? If the faculty inventor only met the licensee contact once for a 15-minute verbal exchange during a conference, does that count as a personal contact? It does not seem reasonable to give such encounters the same weight as contacts in which the faculty inventor has had a professional relationship spanning multiple years. Additionally, percentages alone give no indication of whether factors such as personal contacts, however defined, are causal for licensing of technologies. At best, they only suggest that personal contacts are highly correlated with technology licensing, but personal contacts could be a spurious causal factor.

The literature described above focuses on instances of university technology transfer to existing established private sector firms. Another research stream described in the literature focuses on academic entrepreneurship and university startups as mechanisms for university technology transfer. University startups are new business ventures that are explicitly formed to pursue the commercial development of a technology created at the university. In many cases, faculty inventors are heavily involved in university startups (see e.g., Boh et al., 2016). There are several possible roles that faculty inventors can take on when pursuing a university startup to commercialize technologies created from their research, such as being the founder or co-founder of the company, being a member of the board of directors, acting as president or chief executive officer, or serving as chief technology officer. It is reasonable to infer that in such instances faculty inventors are at least attempting to leverage their social capital to a significant degree to contribute to the success of the venture.

The university technology transfer literature on academic entrepreneurship and university startups primarily concentrates on the characteristics, motivations, and capabilities of faculty entrepreneurs, incentives for pursuing academic entrepreneurship, and critical factors for university startup success (Bengoa et al., 2020). Although the literature in this research stream has investigated what resources, such as human capital, are likely critical success factors, it does not appear to address the use of faculty inventor social capital (see Clarysse et al., 2005; Di Gregorio & Shane, 2003; O'Shea et al., 2005). The personal endowments of aspiring entrepreneurs play a significant role in the nature of the ventures that they tend to pursue and their chances for success (see Bhide, 2000). Social capital

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is assumed to be an important endowment that faculty inventors can bring to bear in their efforts to commercialize the technologies that spawn from their research.

This review reveals a significant gap in the literature as it relates to how university faculty inventors may facilitate successful technology transfer. As such, this work aimed to investigate whether the use of social capital by university faculty inventors (whether this is to identify and solicit potential licensees or facilitate a university startup) is a causal condition for successful technology transfer.

Data and Methods

This section describes the methodology and methods used to examine the use of university faculty inventor social capital as a potential causal factor for successful technology transfer. Causal complexity is the epistemological foundation for the study. Technology transfer is largely a sociological phenomenon. As such, it is likely subject to conjunctural causation, equifinality, and asymmetric causation of outcomes, which are the three characteristics of causal complexity. In consideration of this, the investigation employed a multiple case study (e.g., comparative case study) research design and the qualitative comparative analysis (QCA) method.

Epistemological Approach and Research Questions

Because the phenomenon in question is subject to causal complexity, the traditional methods of statistical inference, such as multiple regression analysis, are not appropriate. These methods assume that the effects of the predictor variables are additive and thus can be examined in isolation (Ragin, 2000). They also assume that there is one best equation to model the data and describe the effects of the predictor variables on the response variable (Ragin). This is at odds with the tendency towards conjunctural causation and equifinality of social phenomena such as technology transfer. Scholars employ statistical inference methods with the goal of understanding how differences in levels of variables explain covariation between variables (see Ragin & Amoroso, 2011). To do this, statistical inference methods require relatively large amounts of data (i.e., more than 50 cases), which is hard to come by for certain phenomena and often precludes a more intimate familiarity with each case that can help one make sense of the patterns in the data.

Given the nature of the phenomenon and the availability of data, the approach used in this study was to examine the diversity among cases of university technology transfer by studying patterns of similarity and difference to identify configurations of case attributes that produce university technology transfer. In doing so, this would reveal whether the use of faculty inventor social capital is a relevant condition. Therefore, rather than use statistical inference methods to test hypotheses, the study employed logical inference methods to answer the following research questions:

> Q1: Is the use of faculty inventor social capital a necessary condition for the occurrence of university technology transfer?
>
> Q2: Is the use of faculty inventor social capital a sufficient but unnecessary condition for the occurrence of university technology transfer?
>
> Q3: Is use of faculty inventor social capital an insufficient but necessary condition of at least one unnecessary but sufficient conjunction of conditions (i.e., an INUS condition) that produces the occurrence of university technology transfer?

Crisp-set Qualitative Comparative Analysis (csQCA) was used for the study. This methodology and method were chosen because they enable the examination of university technology transfer as a causally complex phenomenon. Moreover, the goal of the study was to understand differences in kind rather than differences in degree. That is, the study aimed to investigate fundamental differences in types of causal configurations rather than differences in the magnitudes within causal

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configurations. The crisp-set variant of QCA is well-suited to that end (see Ragin, 2000; Schneider & Wagemann, 2012). Although fuzzy-sets are considered to contain more information, they do not necessarily produce more conservative consistency values when used in QCA studies and thus fuzzy-set QCA (fsQCA) is not necessarily a more rigorous test than csQCA (Rohlfing, 2020). Additionally, the causal conditions used in the study are inherently binary as typically conceptualized in practice.

Conceptualization and Operationalization of Key Constructs

The phenomenon of interest resembles bridging social capital. But mutual trust and reciprocal exchange between university faculty inventors and individuals from prospective licensees or other organizations are primarily employed on behalf of the respective organizations to which the individuals are members, not the individuals themselves.

The study employed a model that consisted of four (4) potential causal conditions and an outcome representative of technology transfer success (see Table 1). For the purposes of the study the use of social capital (SCP) was operationalized as the presence of at least one social or professional connection, that extended beyond a single interaction, between the relevant personnel of the private sector organization that obtained the technology and the faculty inventor of the technology. This included instances in which the faculty inventor was a co-founder of the company that obtained the technology.

Table 1. Causal Conditions and Outcome.

Condition	Descriptive Name	Description	Data Type	Value Range
SCP	Social Capital	Whether there were any significant social or professional connections between the creators of the technology and the organization that contemplated obtaining and assimilating the technology or between relevant decision makers at the private sector organization and the university where the technology was created.	Dichotomous	1 - Yes, 0 - No
ERL	Early-Stage Business	Whether the organization that contemplated obtaining and assimilating the technology is an early-stage for-profit commercial enterprise.	Dichotomous	1 - Yes, 0 - No
TML	Relative Technology Maturity Level	Whether the maturity level of the technology is greater than the typical maturity level of technologies created by U.S. universities.	Dichotomous	1 - Yes, 0 - No
SMB	Small Business	Whether the organization that contemplated obtaining and assimilating the technology had 150 or	Dichotomous	1 - Yes, 0 - No

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		fewer members at the time it began considering the technology.	
UTT	University Technology Transfer	Whether the case is an instance in which university technology transfer occurred.	Dichotomous 1 - Yes, 0 - No

Note. Table created by author.

The other three conditions in the model were based on evidence in the literature that suggests they have an important role in the occurrence of university technology transfer (see Townes, 2022, 2024). Whether the private sector organization was an early-stage venture (ERL) was a condition included in the model. The organization was considered early-stage if it had been operating for 5 years (60 months) or less prior to considering whether to obtain the technology. Status as a small business (SMB) was the third causal condition included in the model. The organization was considered a small business if it had 150 or fewer members (e.g., employees) at the time the organization began considering whether to obtain the technology. Whether the maturity level of the technology (TML) in question was greater than the 80th percentile maturity level for university technologies was the final causal condition included in the model. University technology transfer (UTT) was operationalized as the execution of a license for the technology between the university and the private sector organization.

Hypotheses

Several specific hypotheses were examined to gain insight into the answer for each of the above research questions (Table 2). The first hypothesis was that faculty inventors use of their social capital alone was a necessary and sufficient condition for the occurrence of university technology transfer. This is reflected in the following logical formula:

H1: $\boldsymbol{SCP <=> UTT}$

The bi-directional arrow (i.e., "<=>" symbol) indicates that the disjunction (i.e., multiple conjunctural configuration of conditions) on the left of the symbol (a single condition in this case) is a subset of the outcome specified on the right side of the bi-directional arrow and vice versa (i.e., correlation). It denotes that the disjunction is necessary and sufficient for the occurrence of the outcome of interest on the right of the bi-directional arrow. This solution would indicate that:

1. If the use of faculty inventor social capital is present, technology transfer will occur,
2. If technology transfer occurs, the use of faculty inventor social capital must have been present, and
3. If the use of faculty inventor social capital is not present, technology transfer does not occur.

Such a solution would represent the strongest manifestation of the use of faculty social capital as a causal factor for the occurrence of university technology transfer.

Table 2. Summary of Hypotheses.

Hypothesis	Logical Formula
H1: The use of faculty inventor social capital alone is a necessary and sufficient	$\boldsymbol{SCP <=> UTT}$

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condition for the occurrence of university technology transfer	
H2: The use of faculty inventor social capital alone is a sufficient but unnecessary condition for the occurrence of university technology transfer	$SCP + \sum_{x=1}^{x=n} Conjunction_x => UTT$
H3: The use of faculty inventor social capital is an INUS condition for the occurrence of university technology transfer	$(SCP * \prod_{x=1}^{x=n} Condition_x) + \sum_{y=1}^{y=n} Conjuction_y => UTT$

Note. Table created by author.

The next hypothesis was that the use of faculty inventor social capital alone was a sufficient but unnecessary condition for the occurrence of university technology transfer. This is expressed by the following logical formula:

$$\text{H2: } SCP + \sum_{x=1}^{x=n} Conjunction_x => UTT$$

The formula above uses summation notation for the purpose of simplifying the expression. The addition symbol ("+" sign) indicates logical "OR" and the uni-directional arrow ("=>") indicates that the various configurations of conditions (one of which is SCP by itself) to the left are sufficient to produce the outcome on the right side of the arrow. The summation notation is used to indicate that multiple conjunctural configurations are sufficient to produce the occurrence of university technology transfer. Such a solution would be indicative of the characteristic of equifinality in technology transfer as a phenomenon.

The final hypothesis was that the use of faculty inventor social capital is an INUS condition for the occurrence of university technology transfer. The following logical formula conveys this hypothesis:

$$\text{H3: } (SCP * \prod_{x=1}^{x=n} Condition_x) + \sum_{y=1}^{y=n} Conjuction_y => UTT$$

The multiplication symbol ("*" sign) indicates logical "AND" in the formula. In addition to summation notation, product notation is used to indicate other conditions that act in conjunction with the SCP condition. This solution formula indicates that the use of faculty inventor social capital in combination with one or more other conditions is sufficient to produce the occurrence of university technology transfer. However, that conjunctural configuration is not the only configuration of conditions that produces the occurrence of university technology transfer. Again, such a solution would be indicative of the characteristic of equifinality.

Data Collection

The data and results used in this examination come from Townes (2022, 2024). The focus of that study was the role of technology maturity level in the occurrence of university technology transfer.

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However, the analysis produced an unexpected result regarding the social capital of faculty inventors that was not explored because it was beyond the scope of that study. As such, the purpose of this paper is to explore those unexpected results more thoroughly.

The data were generated by collecting information on 21 cases that occurred during or around calendar year 2019 in which a private sector organization considered whether to obtain and assimilate a technology that was created at a U.S. university (see Table 3). Case identification began with a search of the ABI/INFORM Collection database that was limited to annual reports, articles, cover stories, industry reports, market reports, market research, and news reports from January 1, 2019 through December 31, 2019 found in magazines, newspapers, trade journals, and wire feeds.

Table 3. Case Data.

Case No.	SCP	ERL	TML	SMB	UTT
01	1	1	1	1	1
02	0	0	1	1	1
03	1	1	1	1	1
04	1	0	0	1	1
05	1	1	1	1	1
06	0	0	0	0	0
07	0	0	0	0	0
08	0	0	0	1	1
09	0	0	0	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	0	1	1	1	1
13	1	1	0	1	1
14	0	1	0	1	1
15	1	1	0	1	1
16	0	0	0	0	0
17	1	0	1	0	1
18	0	0	1	0	1
19	0	0	1	0	1
20	0	0	1	0	1
21	0	0	0	0	0

Note. Table created by author. 1 indicates the presence of a condition or the occurrence of university technology transfer. 0 indicates the absence of a condition or the nonoccurrence of university technology transfer.

Additional cases were identified from a search of the *Technology Transfer eNews* archive of entries. *Technology Transfer eNews* (https://techtransfercentral.com/category/tech-transfer-enews/) is a free blog targeted to technology transfer and intellectual property professionals that is produced and published by 2MarketInformation, Inc. The archive of entries is accessible online but is not indexed or abstracted in any research database.

A general search of Google was used to identify more cases. The search was performed using the terms "university licenses", "licenses from", or "COMPANY licenses from university" where "COMPANY" was the name of a specific company of interest that was identified through other

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means such as the Fortune 500 list of the largest U.S. companies based on total revenue. The Electronic Data Gathering, Analysis, and Retrieval (EDGAR) database of the U.S. Securities and Exchange Commission was also searched, using the keywords "license" and "university" as search terms, to identify cases. Candidates were screened based on the number of employees listed on their profile on Yahool! Finance, in their Form 10-K annual reports, or their Form 5500 Series return. The technology transfer records of Saint Louis University were reviewed to identify cases of the non-occurrence of university technology transfer. Additionally, requests to provide up to three (3) cases of the non-occurrence of university technology transfer were made of technology transfer practitioners from other U.S. universities.

Data Analysis

The data were analyzed using the R programming language (The R Foundation, 2023) in the RStudio integrated development environment (RStudio Team, 2023). QCApro was the primary package used in the analysis (Thiem et al., 2018). The study used crisp-set qualitative comparative analysis (csQCA) to analyze the data. Because of the possibility of causal asymmetry of outcomes, the analysis was performed using the occurrence of university technology transfer, as operationalized, as the outcome of interest. The non-occurrence of university technology transfer was not examined.

The analysis of necessity was performed before the analysis of sufficiency because it avoids the problem of hidden necessary conditions and false necessary conditions (see Schneider & Wagemann, 2012). The analysis of necessity entailed determining which conditions, conjunctions of conditions, and disjunctions (logical "OR" combinations) were present in all cases. The logic of necessity using crisp-set data requires that the outcome of university technology transfer cannot occur without the presence of a given condition. The parameters of fit (POFs) used to evaluate necessity were consistency, coverage, and relevance of necessity (RoN). Because of the imprecise nature of social phenomena and social science research methods, several benchmarks for consistency (i.e., inclusion cutoff) of necessity were used (see Table 4). Disjunctions were examined to ascertain whether they were conceptually substantive or not.

Table 4. Minimum Consistency Cutoffs for Necessity and Sufficiency.

Level	Minimum Consistency	Interpretation
1	1.00	Always necessary or sufficient
2	0.90	Almost always necessary or sufficient
3	0.80	Normally necessary or sufficient
4	0.65	Frequently necessary or sufficient
5	0.55	Necessary or sufficient more often than not

Note. Table created by author.

Sufficiency was analyzed once the examination of necessity was completed. The logic of sufficiency using crisp-set data dictates that a condition, conjunction, or disjunction is considered sufficient if the outcome of university technology transfer is present in cases in which the condition, conjunction, or disjunction is present. In other words, the set of cases in which the condition, conjunction, or disjunction is present is a subset of the set of cases with the outcome of university technology transfer.

The analysis examined the data applying three different assumptions for logical remainders in accordance with the Enhanced Standard Analysis procedure of csQCA (see Oana et al., 2021; Schneider & Wagemann, 2012). To generate the conservative (sometimes referred to as "complex") solution, the data were analyzed making no specific suppositions about any logical remainders

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relying exclusively on the empirical data at hand. The parsimonious solution was determined by assuming that logical remainders produced the occurrence of university technology transfer. Finally, the intermediate solutions were generated by incorporating assumptions about the logical remainders using directional expectations of conditions on the occurrence of university technology transfer as a guide.

The conservative solution, which effectively assumes that logical remainders are not sufficient to produce the outcome of interest (i.e., the occurrence of university technology transfer), was determined by first removing logical remainders before testing the remaining condition configurations for sufficiency. Once this was done, the truth table was logically minimized to reveal the conjunctions that were sufficient for the outcome of interest.

Next, the logical minimization was used to determine the parsimonious and intermediate solutions for sufficiency but applying different assumptions about logical remainders. The parsimonious solution assumes that all logical remainders are sufficient to produce the occurrence of university technology transfer. Likewise, the intermediate solution also assumes that logical remainders are sufficient to produce the occurrence of university technology transfer, but implausible counterfactuals and incoherent counterfactuals are removed. However, no implausible counterfactuals and incoherent counterfactuals were identified in the analysis. Additionally, in determining the intermediate solution, the presence of the TML condition was assumed to contribute to the occurrence of university technology transfer. No other directional expectations for other conditions were included in the analysis.

Results

The following section presents the results of the analysis without interpretation. The necessity of the presence and absence of each individual condition for producing the occurrence of UTT was examined at each minimum consistency level. Consistency, coverage, and relevance of necessity (RoN) parameters of fit (POFs) for the presence and absence of each individual condition were calculated for each minimum consistency level (see Table 5).

Table 5. Necessity POFs of Individual Conditions for the Occurrence of University Technology Transfer.

Condition	Consistency	Coverage	Relevance of Necessity
SCP	0.43750	1.00000	0.66667
ERL	0.43750	1.00000	0.66667
TML	0.56250	1.00000	0.57143
SMB	0.62500	1.00000	0.52831
~SCP	0.56250	0.64286	0.33333
~ERL	0.56250	0.64286	0.33333
~TML	0.43750	0.58333	0.42857
~SMB	0.37500	0.54545	0.47619

Note. Table created by author.

The highest consistency POF for any individual condition state was 0.625, which is just below the threshold for being a frequently necessary condition. Four (4) condition states exhibited a

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consistency POF of at least 0.55, which meets the threshold for being a necessary condition more often than not. These included the presence of the conditions TML and SMB and the absence of conditions SCP and ERL (i.e., ~SCP and ~ERL). The coverage POF for both TML and SMB was 1.0 and the relevance of necessity (RoN) POF for each was 0.571 and 0.524, respectively. The coverage and RoN POFs for both ~SCP and ~ERL were 0.643 and 0.333, respectively.

The sufficiency of the presence and absence of each individual condition for producing the occurrence of UTT was examined at each minimum consistency level. Consistency and coverage parameters of fit (POFs) for the presence and absence of each individual condition were calculated for each minimum consistency level (see Table 6).

Table 6. Sufficiency POFs of Individual Conditions for the Occurrence of University Technology Transfer.

Condition	Consistency	Coverage
SCP	1.00000	0.43750
ERL	1.00000	0.43750
TML	1.00000	0.56250
SMB	1.00000	0.62500
~SCP	0.64286	0.56250
~ERL	0.64286	0.56250
~TML	0.58333	0.43750
~SMB	0.54545	0.37500

Note. Table created by author.

The highest consistency of sufficiency POF of 1.000 was observed for the presence of each of the individual conditions. However, the coverage POF for each of the individual conditions was relatively low, indicating that each individual condition explained a relatively low amount of the outcome of interest, which was the occurrence of university technology transfer.

The necessity of the presence and absence of disjunctions for the occurrence of UTT was examined using a minimum consistency that ranged from 1.0 to 0.55. Consistency, proportional reduction of inconsistency (PRI), and raw coverage POFs for each conjunction and disjunction were calculated. The raw coverage was above 0.70 for many of the disjunctions. However, none of the disjunctions were substantively relevant because they were not indicative of higher order constructs.

The sufficiency of the presence and absence of conjunctions and disjunctions for producing the occurrence of UTT were examined using minimum consistency benchmarks ranging from 1.0 to 0.55. Conservative, parsimonious, and intermediate solutions were determined for each consistency benchmark (see Table 7). All solutions exhibited consistency POF values of 1.0 and coverage POF values of 0.875.

Table 7. Sufficiency Solutions for the Occurrence of University Technology Transfer.

Solution Type	Solution	Consistency	Coverage

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Conservative	(ERL*SMB) + (SMB+~TML) + (~ERL*~SMB*TML) + (~SCP*~ERL*TML) => UTT (ERL*SMB) + (SMB+~TML) + (~ERL*~SML*TML) + (~SCP*SMB) => UTT	1.000	0.875
Parsimonious	SMB + TML => UTT	1.000	0.875
Intermediate	SMB + (~ERL*TML) => UTT	1.000	0.875

Note. Table created by author.

The conservative solution exhibited model ambiguity. Two slightly different models, each comprising four conjunctions of conditions, represented the data equally well:

M_1: (ERL*SMB)+(SMB*~TML)+(~ERL*~SMB*TML)+(~SCP*~ERL*TML) =>UTT

M_2: (ERL*SMB) + (SMB*~TML) + (~ERL*~SMB*TML) + (~SCP*SMB) => UTT

Although both models were stable over the range of minimum consistency benchmarks used in the analysis, at the minimum consistency benchmarks of 0.80, 0.65, and 0.55 the solutions shifted from being sufficient to being necessary and sufficient. The two models differed only in one of the four conjunctions.

There was a single parsimonious solution, which was stable over the range of minimum consistency benchmarks used in the analysis. The parsimonious solution was as follows:

TML + SMB => UTT

Under the assumptions of the parsimonious solution calculation, the presence of either the TML condition or the SMB condition was sufficient for the occurrence of UTT. Again, the model shifted from sufficient to necessary and sufficient at the 0.80, 0.65, and 0.55 minimum consistency benchmarks.

There was also a single intermediate solution that was stable over the range of minimum consistency benchmarks used in the analysis. In calculating the intermediate solution, measures were taken to ensure that statements about necessity were not contradicted, and no implausible counterfactuals were included in the analysis. Additionally, the analysis accounted for possible contradictory simplifying assumptions (CSAs). It also incorporated directional expectations regarding the TML condition, whose presence is expected to contribute to the occurrence of UTT based on the literature. This produced the following solution:

SMB + (~ERL*TML) => UTT

The intermediate solution also shifted from sufficient to necessary and sufficient at the 0.80, 0.65, and 0.55 minimum necessity benchmarks.

Discussion

This section presents the major findings and discusses conclusions drawn from those findings. It then discusses the relevance of the study and its implications for university technology transfer

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policy and practice. The section concludes by summarizing the limitations of the study and providing recommendations for future research.

Funding

Summarizes the study findings. In short, the results did not support any of the hypotheses. The results did not corroborate the hypothesis that the use of faculty inventor social capital alone is a necessary and sufficient condition for the occurrence of university technology transfer (H1). If and only if this proposition were true, the analysis would have produced the following solution.

SCP <=> UTT

This solution would have indicated that the SCP condition was a superset of the instances of UTT, thus SCP must be present for UTT to occur and absent when UTT does not occur. Simultaneously, the presence of SCP in and of itself would have been sufficient for UTT to occur. Moreover, there would have been evidence of the superset criteria being satisfied which would have manifested with a consistency of necessity POF value for the occurrence of UTT and a consistency of necessity POF value for the non-occurrence of UTT equal to or greater than 0.80 with a coverage of necessity POF value between 0.70 and 0.90 and a relevance of necessity (RoN) POF value equal to or greater than 0.80. The necessity POFs for the SCP condition alone did not achieve these benchmarks. Therefore, one can logically infer that use of faculty inventor social capital alone, as operationalized in the study, is not a necessary and sufficient condition for the occurrence of university technology transfer.

Table 8. Summary of Findings.

Hypothesis	Finding
H1: The use of faculty inventor social capital alone is a necessary and sufficient condition for the occurrence of university technology transfer	Not supported. The analysis did not produce a solution of the form: $\boldsymbol{SCP <=> UTT}$
H2: The use of faculty inventor social capital alone is a sufficient but unnecessary condition for the occurrence of university technology transfer	Not supported. The analysis did not produce a solution of the form: $SCP + \sum_{x=1}^{x=n} Conjuction_x => UTT$
H3: The use of faculty inventor social capital is an INUS condition for the occurrence of university technology transfer	Not supported. The analysis did not produce a solution of the form: $(SCP * \prod_{x=1}^{x=n} Condition_x) + \sum_{y=1}^{y=n} Conjunction_y => UTT$

Note. Table created by author.

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The study findings did not support the hypothesis that the use of faculty inventor social capital alone, as operationalized in the study, is a sufficient but unnecessary condition for the occurrence of university technology transfer (H2). If the SCP condition alone would have been a subset of the instances of UTT along with other conditions or conjunctions of conditions, it would have been an indication that the SCP condition alone is sufficient for UTT to occur but is only one of several paths that produce the occurrence of university technology transfer. This was not the case. The SCP condition alone was not sufficient to produce the occurrence of university technology transfer in any of the sufficiency solutions.

The study findings did not support the hypothesis that the use of faculty inventor social capital, as operationalized in the study, is an insufficient but necessary condition of at least one unnecessary but sufficient conjunction of conditions that produces the occurrence of university technology transfer (H3). If the analysis had produced a solution in which several conjunctions of conditions produced the occurrence of university technology transfer and at least one of those conjunctions included the presence of SCP, then one could conclude that the use of faculty inventor social capital was an INUS condition. However, this was not the case. In fact, the absence of the SCP condition is an INUS condition in the conservative solutions. The SCP condition falls away entirely in the parsimonious and intermediate solutions.

Interpretation and Implications

This study is relevant to the discourse about university technology transfer because it challenges previously held notions about the influence of faculty inventor social capital on the occurrence of university technology transfer outcomes. If the results are verified in other studies, it suggests that university technology transfer practitioners should rethink how university faculty are encouraged to engage in the technology transfer process. It would also influence the types of policies and programs that policymakers and university administrators implement to incentivize faculty participation in university technology transfer efforts.

Although the results of this examination may seem counterintuitive and appear to contradict the results of other studies, there are several possible explanations that rationalize the differences. The current study used a more stringent operationalization of social capital than the survey research found in the literature. Simple awareness of a potential licensee and knowledge of their contact information did not qualify as social capital in the current study, whereas it likely was considered social capital in the survey research in the literature. It may be the case that faculty inventors have relatively few “strong” personal or professional relationships with research and development (R&D) staff at private sector organizations that can contribute to the successful transfer of university technologies. Or it could be that strong form and weak form bridging social capital of faculty inventors influence the technology transfer process in different ways.

In the current study, most of the cases in which the use of inventor social capital was present were instances in which the licensee was a university startup. University startups accounted for about one-third of the cases in the study. Despite this, the presence of the SCP condition was not relevant in the parsimonious and intermediate solutions. The effect of one or more of the other conditions might be far more important than the use of faculty inventor social capital in producing the occurrence of technology transfer and thus masks the influence of faculty inventor social capital.

In each of the conservative solutions, the absence of the use of faculty inventor social capital (~SCP) was an INUS condition for one of the conjunctions. It may be the case that when faculty inventors do attempt to use their social capital to facilitate technology transfer, it is in support of technologies that are less suitable for commercialization. There are non-technical dimensions of technology commercialization that come into play. The decision of a faculty inventor to use their social capital may be driven by an emotional investment in the technology, rather than the merits of the technology. Instances in which faculty inventors use their social capital to facilitate technology transfer, particularly via university startup, may be correlated with technologies that are less suitable for commercialization. Technologies that are more suitable for commercialization might not require

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faculty inventors to use their social capital to facilitate technology transfer because the potential benefits they offer are more readily apparent. Thus, the absence of faculty inventor use of social capital would be indicative of a technology that is more suitable for commercialization.

Should these results be validated by other studies, they would have implications for professional practice and public policy. With regard to public policy, it would be unproductive for policymakers to incorporate the formation of social capital as an objective for policies and programs intended to increase the incidence of university technology transfers. This could warrant rethinking programs such as industry-university cooperative research centers (IUCRCs) and the level of support for conferences.

As it pertains to the practice of university technology transfer, these results (should they be verified in other studies) suggest that university technology transfer practitioners need not rely on the social capital of faculty inventors to effectuate the transfer of technologies from academia to the private sector. This could also have an impact on the working relationship between university faculty and technology transfer practitioners.

Study Limitations

There are caveats regarding the application of QCA in multiple case study research designs. The cases, conditions, and attributes selected for the analysis can have a significant impact on the research results and thus the conclusions drawn about causal relations (Sehring et al., 2013). Careful consideration of each of these elements is required and one must be careful to avoid subjectivity in the analysis. The way the conditions are operationalized can help mitigate these challenges. However, different operationalizations might produce different results.

For practical reasons, the number of factors that could be included in the study had to be limited to keep the analysis and interpretation of results manageable. This may have limited the variety of cases that can be included in the study. While this provided for better comparison of the selected cases, it limits the generalizability of the results and exacerbates the challenges imposed by limited empirical diversity.

In an ideal analysis, the sample of cases would include all possible combinations of conditions, except for those that are physically impossible. This is generally not the situation given the nature of social phenomena, the constraints encountered when conducting research studies, and the limitations regarding the practical number of cases that can be included when QCA is employed in a research study design. As such, one must take this into consideration when evaluating the validity and generalizability of inferences drawn from the analysis.

The study used crisp-set QCA (csQCA) which may be limited in its representativeness of the phenomena of university technology transfer and the constructs used in the study because of its binary approach. The constructs used in the study were conceptualized in binary terms, which is often useful for thinking about social phenomena. However, these phenomena may manifest in terms of degrees. Because of this the study is likely more revealing of differences in kind rather than differences in degree. Employing fuzzy-set QCA (fsQCA) might reveal more subtle relationships.

The operationalization of the use of faculty inventor social capital condition (SCP) is another limitation. For cases in which the organization that considered obtaining the technology was a university startup in which the faculty was involved, the SCP condition was coded as present. Case coding guidelines specified that for cases in which the organization that considered obtaining (e.g., licensing) the technology was an established company unaffiliated with the university, the SCP condition was coded as absent unless there was specific evidence that there was use of faculty inventor social capital. It is possible that the use of faculty inventor social capital did in fact occur in one or more of these latter types of cases in which this condition was coded as absent.

Recommendations for Future Research

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There are several opportunities to extend the research presented in this article. When using QCA, one defines a domain of homogeneity from which to draw cases. The analysis examines heterogeneity within this domain of case homogeneity. Future research can further narrow the case domain by doing separate analyses based on the nature of the private sector organization that considered obtaining the technology. That is, cases in which the private sector organization that considered obtaining the university technology was an established company unaffiliated with the university can be analyzed separately from cases in which a university startup was the mode of technology transfer.

One could also replicate the study by focusing on cases in different time periods. The current study incorporated a temporal dimension to define the case domain. Only cases that occurred during or around calendar year 2019 were included. Future research can focus on different calendar years or expand the time period to multiple calendar years.

Finally, future research can employ different operationalizations for the use of faculty inventor social capital. The current study conceptualized social capital as overt efforts of faculty inventors to leverage their connections across social groups – what one could think of as strong form bridging social capital. It may be possible for the effects of faculty inventor social capital to manifest in more indirect manners to facilitate university technology transfer. For example, a faculty inventor that is an active member in an association in which individuals from potential licensee organizations are also active members might create social capital that can contribute to the eventual transfer of technologies that the faculty inventor creates to one of those potential licensee organizations without direct interaction between the faculty inventor and a person from the licensee organization. This is an example of what could be characterized as weak form bridging social capital.

Conclusion

A review of the university technology transfer literature revealed a gap regarding our understanding of the role of faculty inventor social capital in the technology transfer process. The aim of this study was to investigate whether the use of faculty inventor social capital is likely a causal condition for producing desired university technology transfer outcomes. This question was examined using a multiple case study approach and the qualitative comparative analysis (QCA) method. The results of the study suggest that the use of faculty inventor social capital is not a necessary, sufficient, or INUS condition for the occurrence of university technology transfer. Moreover, the non-use of faculty inventor social capital might be an INUS condition associated with the successful conveyance of technology from universities to private sector firms. Should these results be verified in other studies, it would have significant implications for both public policy and the practice of university technology transfer.

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