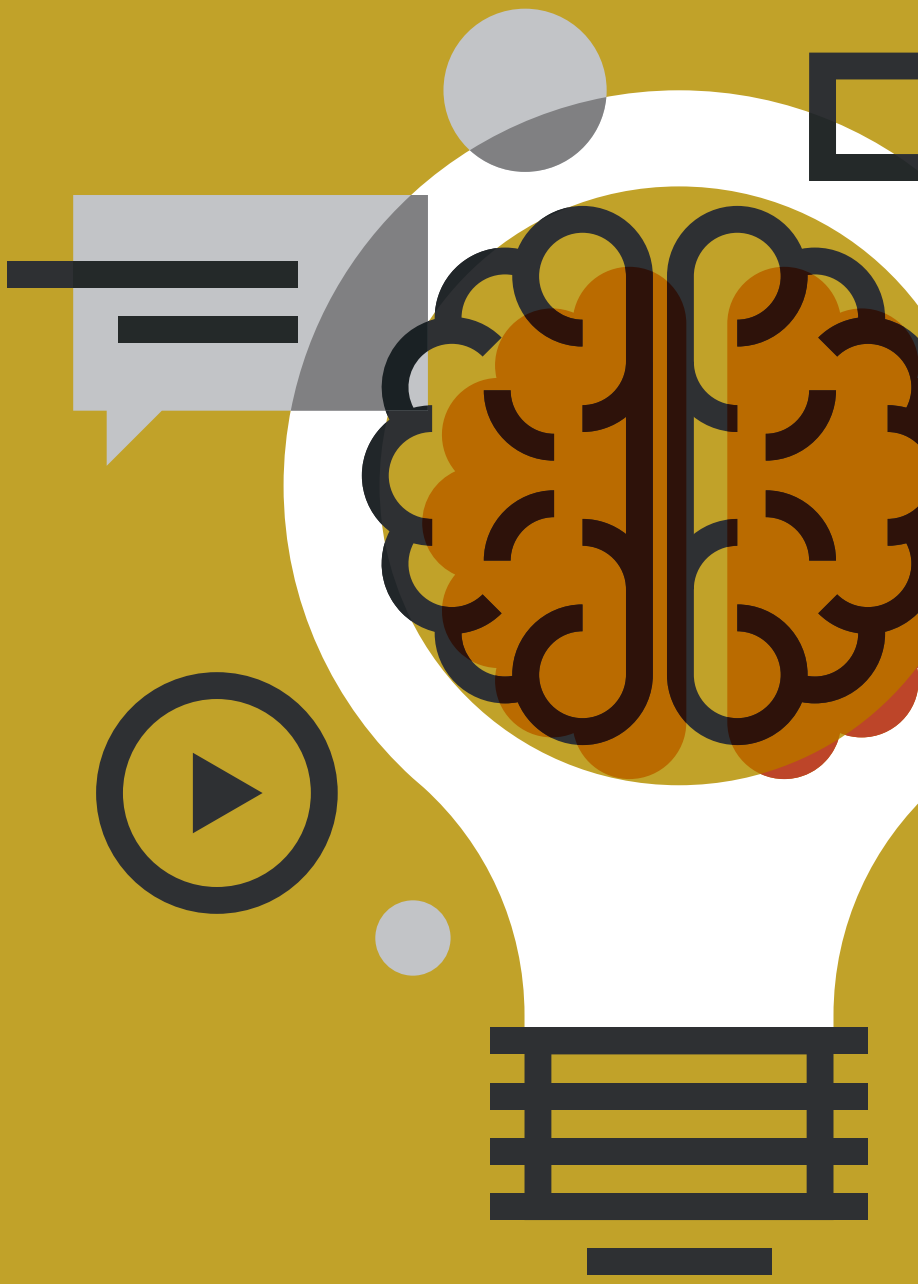
tillväxtanalys

En del av ramprojektet
”Hur kan offentliga aktörer rigga samverkan för ökad innovation?”



PM 2018:04

University-industry collaboration on innovation: a literature review and synthesis

WHAT FACTORS STIMULATE university-industry collaboration on innovation? To answer this question 40 of the most often cited peer-reviewed articles in the field were reviewed. The results were used to construct a hypothetical model that describes the institutionalization of university-industry collaboration. The model will be applied in future studies of collaboration planned by the agency.

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Förord

Frågeställningarna inom tillväxtpolitiken är komplexa och kräver en djuplodande och mångsidig belysning för att ge kunskap om vad staten kan och bör göra. Tillväxtanalys arbetar därför med vad vi benämner ramprojekt. Ett ramprojekt består av flera delprojekt som bidrar till att belysa en viss frågeställning. Den här studien är ett av flera kunskaps-underlag för ett pågående ramprojekt med rubriken *Hur kan offentliga aktörer rigga samverkan för ökad innovation?* Ramprojektet kommer att avrapporteras under första kvartalet 2019.

Den svenska innovationspolitiken har i allt högre grad kommit att kännetecknas av olika typer av samverkansprogram där samverkan och ”samproduktion” ska leda till tillväxt och överspillning av kunskap. De frågor vi ställer i ramprojektet är: Leder samverkan till ökad innovation och tillväxt? Vilka aktörer tjänar på att delta i ett samverkansprogram? Hur organiseras och implementeras programmen för att ge bäst effekt?

Föreliggande studie är en litteraturgenomgång av den högst citerade forskningslitteraturen på området universitet och näringslivssamverkan. Syftet är att genom kvalitativ innehålls-analys identifiera faktorer som har inverkan på etablerandet av olika samverkansrelationer. Ett analytiskt ramverk har utvecklats, ett ramverk som ska användas för att genomföra ett antal fallstudier av hur deltagande i två större samverkansprogram (Vinnovas Utmanings-driven Innovation och KK-stiftelsens program HÖG) stimulerat kunskapsutveckling och innovation i samspelet mellan akademi och näringsliv.

Studien har författats av dr. Karolin Sjöö, analytiker vid Tillväxtanalys, och Tomas Hellström, professor i innovationsstudier vid Lunds universitet.

Stockholm, april 2018

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Avdelningschef, Innovation och grön omställning
Tillväxtanalys

Table of Contents

Sammanfattning

Inledning

Syftet med den här studien är att genom kvalitativ innehållsanalys identifiera faktorer som har inverkan på etablerandet av innovationsinriktade samverkansrelationer. Till grund för studien ligger 40 högt citerade artiklar identifierade via artikeldatabasen Web of Science. På basis av studiens resultat föreslås ett analytiskt ramverk som beskriver hur samverkan institutionaliseras.

Resultat

Resultatet av litteraturgenomgången har ordnats i sju olika teman och två överordnade dimensioner. De sju temana är resurser, universitetsorganisation, gränsöverbryggande funktioner, erfarenhet av samverkan, kultur, status, politisk och geografisk kontext. De två överordnade dimensionerna är (1) tidsramen inom vilken en aktivitet kan genomföras eller en omständighet påverkas och (2) huruvida aktiviteten eller omständigheten påverkar aktörer/aktiviteter eller det sammanhang i vilket dessa aktörer/aktiviteter agerar/äger rum.

En hypotetisk logikmodell

De identifierade temana och dimensionerna ligger till grund för en hypotetisk modell som beskriver hur universitets- och näringslivssamverkan institutionaliseras över tid. Modellen ska ses som ett antal hypoteser som beskriver de mekanismer som sammanlänkar aktiviteter och omständigheter i en process mot ökad institutionalisering av samverkan. Sekvenseringen bygger på antaganden rörande hur olika faktorer kan påverka denna process givet en situation av låg institutionaliseringsgrad (lite samverkan). En hypotes är till exempel att det är både lättare och går snabbare att öka resurser än att förändra kultur. När väl samverkan institutionaliserats kommer relationen mellan de olika faktorerna i modellen troligtvis att se annorlunda ut. Man kan då till exempel anta att en kultur av samverkan kan få universitet och företag att satsa mer resurser på samverkan. I den utsträckning samverkan ger hög status kan det leda till en positiv spiral där fler forskare och företag väljer att engagera sig i olika samverkansrelationer. Sammanhang som karaktäriseras av institutionaliserad samverkan kräver därmed en mer komplicerad modell.

Fortsatt lärande

De hypoteser som ligger till grund för modellen behöver undersökas empiriskt innan den kan användas för att designa och utvärdera interventioner. Därutöver behövs fördjupad förståelse för relationen mellan olika faktorer i sammanhang karaktäriserade av hög institutionaliseringsgrad. I framtida studier avser därför Tillväxtanalys i ett antal fallstudier undersöka de mekanismer som på olika sätt sammanlänkar aktiviteter och omständigheter i miljöer där samverkan institutionaliserats i olika hög grad.

Summary

Introduction

The purpose of this study is to use qualitative content analysis to map factors that stimulate the formation of collaborative relations. We conduct a systematic review of the academic literature on university-industry collaboration and identify 40 frequently-cited articles from the database Web of Science. The review provides the basis for a hypothetical model that describes a process of increasing institutionalization of collaboration.

Results

The literature review is summarized across seven main themes and two overarching dimensions. The themes are resources, university organization, boundary spanning functions, collaborative experience, culture, status centrality, policy and geographical context. The two dimensions are (1) the relative time frame needed to realize an activity/-condition and (2) whether the activity/condition was primarily related to actors/actions or to the environment in which actions/activities took place.

A hypothetical logic model

The themes and dimensions are used to construct a hypothetical model that describes how university-industry collaborations are institutionalized over time. The model suggests a number of hypotheses that describe the mechanisms that link activities and conditions in a process that tends toward increasing institutionalization. The sequencing of these activities and conditions builds on assumptions about how certain factors can affect the level of institutionalization, given a context in which baseline levels are relatively low. For example, the model assumes that increasing the level of resources available is an easier and faster way to reach increased institutionalization than changing culture. However, once collaboration is institutionalized, the relations between the factors in the model may change. For example, it is possible that we may instead observe a relationship where a new culture drives additional resources into an area. Further, when engaging in collaboration is rewarded with higher status, additional researchers and companies are more likely to join. In short, a more complex model may be required depending on the specific context and levels of institutionalized collaboration.

Future learning

The hypotheses on which the model is based require additional empirical evidence before it can be used in the design and evaluation of interventions. Furthermore, we need a better understanding of the relationship between factors when the status quo is characterized by high levels of institutionalization. Therefore, the agency plans to study, through case studies, the mechanisms that link activities and conditions in variable contexts for institutionalized collaboration.

1 Introduction

Academic entrepreneurship, outreach, third mission, and university-industry collaboration, are key concepts at the center of an emerging research specialization in Science, Technology and Innovation (STI) policy studies. Unlike traditional innovation/industrial policy, where the expectation is that the private sector alone would drive innovation, the new focus is on the role of universities and their extended networks in transforming research into products and services. Classical studies on collaborative and networked innovation processes (e.g. Powell et al., 1996) have been extended to include conditions for university-industry partnerships. Furthermore, theoretical approaches such as Mode 2, Triple-Helix and post-academic science have been suggested to help explain circumstances that affect such partnerships (Gibbons et. al., 1994; Etzkowitz, & Leydesdorff, 2000; Ziman, 1996).

Previous attempts to order this research systemically tend to suffer from at least one of two shortcomings. First, meta-studies in this area tend to gloss over the details of the main variables at play (e.g. listing of factors affecting collaboration rather than providing detailed analysis of their content). Second, factors affecting collaborative innovation and its outcomes are not always conceptualized causally, which makes it difficult to theorize about key relationships (e.g. Rothaermel et al., 2007; Geuna & Muscio, 2009). This study relies on a combination of systematic literature review, qualitative content analysis and draws on logic-model construction, to describe and analyze actions and conditions that promote co-production of innovation. The resulting information is ordered into a hypothetical model that, after empirical validation, can be used for constructing a program theory for policy instruments aimed at co-production of innovation.

This paper deals with a subset of university outreach that has innovation as an explicit purpose and consequence. This means that many other types of university outreach are excluded, viz. commissioning of practitioner teaching (Hudson, 2006), curricula alignment, student placements, social networking (Molas-Gallart & Castro Martinez, 2007), public understanding of science, involvement in social and cultural life, and participation in policy making (PRIME, 2005).

While these types of outreach may result from collaborative innovation, or support aspects of it, they are not the focus of this study. Instead, this paper analyzes innovation-related collaboration that focuses on R&D activities such as formal research consulting work, joint R&D projects and programs, patenting and spin-off creation (Ramos-Vielba & Fernandez-Esquinas, 2012; Fuentes & Dutrénit (2012), or purchase of prototypes developed at universities, and exchange of use of facilities and equipment between universities and firms (Scharinger et al., 2002).

Throughout the paper we use the following terms to refer to this type of outreach: collaboration, outreach, collaborative innovation, co-production, technology transfer and research collaboration. It is also worth noting that while previous research reviewed in this paper identify factors that support technology transfer and research collaboration, it usually does not go into detail as to how this dependent variable is constituted. This is a weakness of many previous studies, and one that inevitably transfers to any meta-study.

This paper will proceed as follows. In Section 2 the systematic literature review will be outlined, in terms of collection, analysis and model construction. Section 3 will present the

main categories of collaborative activities and conditions, going into detail regarding the underlying research results. Finally, Section 4 will propose a hypothetical model where these categories (or result themes) is conceptualized as an idealized sequence of causes and effects.

2 Approach

2.1 Data collection and analysis

The material for this study was collected using a systematic literature review, coupled with a qualitative content analysis of the studies reviewed. The systematic literature review aimed at collecting studies that were representative, empirically-based, and peer-reviewed on the topic of co-production of innovation, using explicit search criteria (Pettigrew & Roberts, 2006). To elicit and select relevant studies the authors undertook a keyword search in the Web of Science database using publication type 'English language journal' and keywords 'innovation' AND 'empirical.' These were combined with each of the following keywords/phrases in separate searches: *academic entrepreneurship, mode 2, outreach, third mission, third stream activity, third task, triple helix, university-industry interaction/collaboration/cooperation, university-industry, PPP, co-production, technology transfer*. The lower cut-off point for inclusion in the sample was 20 citations.
A manual selection was conducted to ensure that the studies were indeed empirically-based journal articles addressing academic-industry cooperation and innovation. Finally, a selection of the 40 highest cited articles was retained for subsequent analysis.

The authors cross-read the articles and jointly documented each study according to empirical sample, type of actors involved, type of collaborations, factors/activities identified as stimulating collaboration, and outcomes.[1] These protocols were then subject to a qualitative content analysis (Kuckartz, 2014) where common results were identified, specifically with regard to activities/factors stimulating collaborative innovation and outcomes. These results were clustered into themes/categories applying a concept mapping approach, and then ordered according to basic, identifiable patterns (Rosas & Kane, 2012). This produced two basic dimensions that were used to order seven identified themes in the results: university organization, boundary spanning functions, collaborative experience, culture, status centrality, policy context and geographical context. The basic dimensions were (1) the relative time frame needed to realize an activity/condition, and (2) whether the activity/condition was mainly related to actors/actions or to the environment in which actions/activities took place.

2.2 A logic model approach

Using the basic dimensions, it was possible to arrange result themes into a hypothetical model, where some types of collaborative conditions/actions could be said to precede others in terms of their *availability* of intervention and *amenability* to change (see Section 3). It is important to point out that the ordering of the results into an outcome line or logic model is a highly hypothetical exercise in a study of this size. Nevertheless, it is an interesting one in terms of methodological and analytical illustration and as a stepping stone for further elaboration. In this case we constructed a model as a 'scaffold' to order causal insights drawn from the literature. A key focus was how activities and conditions may afford change in the sense of leading to other activities/conditions (Hellström & Jacob, 2017). This means that the authors needed to carefully elaborate the content of the respective result themes (Section 3), as well as potential linkages in terms of how one outcome may lead to another outcome (Section 4) through some operative mechanisms

[1] See Appendix for questions that guided the literature review.

(e.g., resources and activities) (Cooksy, Gill & Kelly 2001).[2] In ordering the results it became clear that some of the themes were more action-oriented while others described conditions for action. It was natural to put the action themes in the beginning of the model followed by the conditions (using the availability and amenability criteria). This implies a number of potential feedback relationships in the model where, once conditions exist, they will affect the likelihood or viability of actions. For the sake of simplicity these have been omitted from the model, but some general reflections on the nature of such feedbacks are offered in Section 4 (for an extended discussion on logic model construction see Wyatt Knowlton & Philips, 2013).

[2] The model presented in Section 4 is not explicitly ordered according to the classic 'resources, activities, outputs, outcomes' logic, but can easily be applied according to such logic, depending on how the specific program is conceptualized. It can therefore also be conceptualized as a 'path-diagram' (Weiss, 1972) or as an 'outcome line' (Mohr, 1995).

3 Results

The review has identified several enabling factors – i.e., variables that affect the likelihood of university-industry collaborative innovation. These factors are arranged in Table 1 according to two 'meta-dimensions'; actor and environmental variables as well as the timeframe for enacting change in the respective enabling factor (short, medium or long-term).

Table 1 Enabling factors for university-industry collaborative innovation

Time-frame for intervention/change	Actor variables	Environmental variables
Short term	Resources (funding, monetary incentives)	Government incentives (e.g. legislation and monetary incentives)
	University organization and IPRs	
	Boundary spanning functions	
Medium term	Collaborative experience	Geographical context: Regional orientation (entrepreneurship and R&D intensity)
Long term	Culture	Geographical context: Proximity, R&D intensity, entrepreneurship
	Status/centrality of actors (R&D intensity, excellence, and size)	

3.1 Enabling factors on the actor level

3.1.1 Resources

The first enabling factor is the provision or existence of organizational resources for pursuing collaboration. This factor may be connected to *a need for additional funds* to pursue research among academics, where this need is not satisfied by available research funds (Tartari & Breschi, 2012; D'Este & Perkmann, 2011; Franco & Haase, 2015). While the literature emphasizes the resource factor, in the present sample of studies there is no real specification regarding how resources ought to be distributed to achieve desired effects. The blanket descriptor for this is simply *available resources to cooperate* (Tartari & Breschi, 2012). The literature does however specify two resource types, namely availability of *local seed-funding*, which pertains specifically to the creation of spin-off firms (Debackere & Veugelers, 2005), and access to *non-public funding*, i.e., not distributed via government channels (Azagra-Caro, Archontakis, Gutiérrez-Garcia et al., 2006; D'Este & Patel, 2007; D'Este & Perkmann, 2011). We therefore conclude that the availability of local, non-government funding may be a key enabler.

An additional enabling resource mentioned in the literature is time availability (Locket, Kerr, & Robinson, 2008). Time is a key resource, which is connected to how financial means are transformed into time available for collaboration, and the simple fact that developing and maintaining mutual engagement and interest requires time (Gertner, Roberts & Charles, 2010). This overlaps partially with the organizational factor below,

since the planning of researchers' time must allow room for them to respond to company requests of a more immediate nature (Locket, Kerr, & Robinson, 2008).

3.1.2 University organization and Intellectual Property Rights (IPRs)

Organizational level resources, as discussed above, are connected to organizational capacities for collaboration in various ways. The most immediate and obvious of these is the provision of incentives to collaborate among actors. Many perceive monetary and non-monetary rewards for engaging in technology transfer as being insufficient (Siegel, Waldman, & Link, 2003). Incentives must be built into incentives systems that off-set the significant risks of commercializing, e.g. through substantial royalties (Debackere & Veugelers, 2005). In addition, and perhaps most importantly given the number of references dealing with this, is the existence of a support infrastructure for collaboration. We may distinguish between a 'passive' support structure in the form of an enabling organizational form, and an 'active' support structure in the form of dedicated functions for supporting collaboration. The former may be an organizational structure that is balanced or adapted to foster co-existence of entrepreneurial and scientific work, e.g. through cross-cutting, interdisciplinary divisions (Van Looy et al., 2004). It may also refer to a decentralized management structure, where research groups are given autonomy in how to management their industry relations (Debackere & Veugelers, 2005). Generally, excessive bureaucracy is perceived (both by researchers and managers/entrepreneurs) as being a barrier to effective technology transfer (Siegel, Waldman, & Link, 2003; Franco & Haase, 2015). Perhaps for this reason, network participation is found to be an important enabler, especially researcher networks that extend beyond the university's support infra-structure, and beyond what the university offers, are of great import for collaboration (Gilsing, van Burg & Romme, 2010).

The latter, more active form of organizational enabler is represented by, for example, a liaison office with crucial expertise and networking abilities for collaboration (Van Looy et al., 2003), and various types of support systems for industrial consultancy (Debackere & Veugelers, 2005). Other types of support systems frequently quoted in the literature include university research parks (Link & Scott, 2007; Caldera & Debande, 2010), which stimulate a two-way flow between universities and industry, and university affiliated incubators supporting knowledge transfer between university and industry (Bergebal-Mirabent, Lafuente, Solé, 2013). Technology transfer offices are one important instantiation of an active enabling structure. The existence of a TTO increases the value of the patent resulting from industry collaboration (Petruzelli, 2011). In addition, TTOs that are larger and more densely staffed, generate more licensing agreements and more R&D contract income (Caldera & Debande, 2010; Siegel, Waldman, & Link, 2003).

An important part of the organizational dimension is the impact on collaboration of rules and regulations. A general observation is that an excessive legal framework regulating collaboration is counterproductive (Franco & Haase, 2015). More specifically, research found that the existence of rules relating to copyright or the participation of researchers in contract R&D has a negative effect on the number of such contracts, but no effect on the income generated from contracts. However, both types of steering decrease the incentive to engage in collaboration (Caldera & Debande, 2010). This may be related to the observation above on the effect of bureaucracy. On the other hand, the existence of rules that regulate conflicts of interest has a positive influence on both number of R&D contracts and the income generated by those contracts, and policies for royalty sharing also tend to have a positive effect on licensing income (Caldera & Debande, 2010).

The import of rules and regulations is far from obvious, but in general we may conclude from the literature that too many or unclear rules hamper collaboration, and some rules enable and enrich collaboration once it has been established. The review of the literature confirms this with regard to IPR policies. Unclear IPR arrangements tend to hinder collaboration (Locket, Kerr, & Robinson, 2008), yet many entrepreneurs and business managers believe universities exercise their intellectual property rights too aggressively, which in turn is perceived to hinder effective technology transfer and collaboration (Siegel, Waldman, & Link, 2003). With these provisos, we conclude that transparent and unambiguous regulations with regard to IPRs are a positive stimulant for collaboration (Debackere & Veugelers, 2005).

The last category under this heading is what we refer to as educational scope. This is the fact that the educational structure and composition of the university impacts its propensity to collaborate. For example, education concentration in certain subjects such as engineering is positively related to collaboration and spin-offs (Bergebal-Mirabent, Lafuente, Solé, 2013; Azagra-Caro, Archontakis, Gutiérrez-Garcia et al., 2006). Also the presence of a medical school at the university has a positive effect on the number of R&D contracts received, and polytechnic universities typically generate higher incomes from such contracts (Caldera & Debande, 2010).

3.1.3 Boundary spanning functions

Closely connected to the organizational factor above, is that 'boundary spanning functions'. We have elected to separate the boundary spanning functions from the organizational structure factor, since the former seems to revolve more around activities and actors already engaged in creating collaboration, outside of the formal structures of the university. In this sense the factor is a precursor to the next one, namely that of 'collaborative experience'. The clearest examples here consist of those inter-organizational connections that individuals and groups perform in connection with projects.

The centrality of *project champions and sponsors in both university and industry* who span university-industry boundaries, is pointed out in the literature (Van Looy et al., 2003), as is the importance of *boundary spanning roles* for knowledge transfer (Gertner, Roberts & Charles, 2010; Franco & Haase, 2015). This is about initiating projects and connecting them across the university-industry divide, as well as providing *efficient communication channels* from industry to the research results of universities (the lack of such channels is perceived by actors as a barrier to collaboration) (Guan, Yam, & Mok, 2005). Such *expert exchange between university and industry* is identified by the literature as a positive driver for collaboration, and the success of such knowledge acquisition is positively associated with the frequency of communication between a firm's technological expert(s) and ditto people at the university (Sherwood & Covin, 2008; Huber, 1991). Not unexpectedly, *personal relationships* are perceived to be more important to effective technology transfer than formal instruments (i.e. TTOs or liaison offices) (Siegel, Waldman, & Link, 2003; Casper, 2013). However, one more formalized instance of the boundary spanning function is identified as beneficiary, namely that of *memberships in cluster or intermediary organizations*. Being a member of an external intermediary organization is positively associated with forming linkages to universities in the region covered by the organization (Kodama, 2008).

3.1.4 Collaborative experience

One of the most prevalent predictors of collaboration found in the material is that of prior experience in collaboration. This is identified as an important factor among researchers, on the university level as well as in firms. Among researchers it was found that previous experience in collaboration has a positive influence on further contract research, consulting and collaborative research (Schartinger et al., 2002; D'Este & Patel, 2007; D'Este & Perkmann, 2011). Similarly, Thune (2009) found that prior collaborative experience among researchers (in this case supervisor-doctoral student teams) and firms is positively related to the likelihood and success of collaboration.

On the university level, it was found that universities that have collaborated with industry for a long time are more likely to collaborate in the future (Wen & Kobayashi, 2001). Experience with spin-off firms are likewise positively related to collaboration (Bergebal-Mirabent, Lafuente, Solé, 2013) and, correspondingly, older TTOs tend to be more efficient than younger ones (Siegel, Waldman, & Link, 2003). When it comes to firms, experience matters as well, for example already having collaborative agreements with other actors tend to stimulate further collaboration among firms (Segarra-Blasco & Arauzo-Carod, 2008). Prior experience is such a strong predictor, that even previous collaboration deemed unsuccessful by firms was shown to be positively associated with the probability of interacting with universities again (Tödling, Lehner & Kaufmann, 2009).

Prior experience can be hypothesized to stimulate collaboration through various learning processes, e.g. through institutionalization and routines. Previous ties, such as filing of joint patents, in fact increase the value of patents resulting from UI collaboration (Petruzelli, 2011). Personnel exchange between university and industry is one way of creating such institutionalization, e.g. by the training and transfer of people (Pérez Pérez & Martínez Sánchez, 2003). Finally, and perhaps not unexpectedly, familiarity and trust resulting from such sustained interaction is an important component of institutionalization and learning.

Personal contacts between academics and business has for example been shown to improve the likelihood of commercialization of academic results (Casper, 2013) and Sherwood and Covin (2008) show that partner familiarity and trust is positively related to the perceived success of knowledge acquisition between firms and universities.

3.1.5 Culture

Cultural factors may bring university researchers and private business firms both closer together and further apart. University researchers' care for their academic freedom and their fear of losing it or it being constrained when engaging in industry collaboration typically keeps them from pursuing such ventures (Azagra-Caro, Archontakis, Gutiérrez-Garcia et al., 2006; Tartari & Breschi, 2012). Similarly, firm representatives may stay away from collaboration if they experience too big a divergence between their own objectives and interests of the researchers' (Fontana, Geuna, & Matt, 2006). Another concern that could potentially hold researchers back from collaboration is related to the possibility that an industry partner may want the results of a joint project to be kept secret, which may hinder academic publication. While there is an indication that researcher with knowledge and experience of working with IPRs may let an increased concern about secrecy keep them from collaborating, the effect is weak (Tartari & Breschi, 2012). The overall picture conveys no correlation between such worries and the propensity to collaborate (Tartari & Breschi, 2012). Being confronted with the 'open science' paradigm,

firms may, on the other hand, shy away from collaboration in fear of revealing trade secrets (Fontana, Geuna, & Matt, 2006).

Different work routines may also make researchers and firms repel each other. Different time horizons seem to be particularly problematic; firms work within a time-to-market logic incompatible with the longer time-frames typically employed by university researchers (Locket, Kerr, & Robinson, 2008; Fontana, Geuna, & Matt, 2006). What is more, firms may rule out collaboration only because they do not have the time it takes to establish contact with a university (Locket, Kerr, & Robinson, 2008).

Expressed in more general terms, some of the reviewed articles demonstrate that a lack understanding and mutually negative perceptions of 'the other' hinder transactions (Siegel, Waldman, & Link, 2003). Firms may, for example, perceive academia as out of touch with the 'real world' (Locket, Kerr, & Robinson, 2008). Others find that such barriers can be overcome through social interaction leading to deeper commitment and the development of a shared language (Gertner, Roberts & Charles, 2010; Locket, Kerr, & Robinson, 2008). Such interaction is facilitated by the employment of a person who understands both the university and the business context. This person may for example be a recent university graduate (Gertner, Roberts & Charles, 2010) or a researcher taking on the role of an 'entrepreneurial coach' (Locket, Kerr, & Robinson, 2008).

The review shows university culture to be positively correlated with activities that transgress the borders of academia. Once created, entrepreneurial university culture seems to be self-reinforcing; with role models engaging in collaboration and entrepreneurship, and concepts such as 'entrepreneurship', 'spinoff', and the 'Third Mission' becoming positively charged, which in turn breeds positive attitudes (Locket, Kerr, & Robinson, 2008), and stimulates collaborative activity (Gilsing, van Burg, & Romme, 2010; Van Looy, Debackere, & Andries, 2003). Entrepreneurial culture can be fostered in various ways; through institutional encouragement (Azagra-Caro, Archontakis, Gutiérrez-Garcia et al., 2006), clear incentives (Locket, Kerr, & Robinson, 2008) that balances rewards for both scientific publication and research pursued in collaboration with industry (Van Looy, Ranga, Callaert, et al., 2004), and curricula oriented towards business and law (Van Looy, Debackere, & Andries, 2003).

3.1.6 Status centrality of actors (R&D intensity and size)

Universities, researchers, and firms with high status relative to others are more likely to collaborate and more likely to be chosen as partners. On the level of the individual faculty member, reputation stands out as being strongly associated with industry collaboration (Giuliani, Morrison, Pietrobelli, et al., 2010; Schartinger, Rammer, Fischer, et al., 2002; Fontana, Geuna, & Matt, 2006). One of the reviewed articles operationalize reputation as the size of a researcher's network and finds that a wealth of connections among domestic research colleagues is linked with a large number of industry collaborations (Giuliani et al., 2010). No answer is however provided as to how this link operates; whether a wide network leads to more industry contacts or whether a large number of industry contacts lead to a wider network of academic peers, assuming that such contacts appeal to research colleagues. Status can also come with seniority; hence some of the articles investigate whether being a full professor is positively correlated with collaboration. The evidence is mixed; some find professors to be more likely to collaborate (D'Este & Patel, 2007), whereas others do not.

Status centrality may be a result of academic performance. The reviewed literature provides mixed messages when it comes to the link between status acquired through excellent research and the propensity to collaborate with industry partners. Some studies find scientific qualifications and productivity to be positively correlated with industry interaction (Franco & Haase, 2015, also Gulbrandsen & Smeby, 2005) while others find no significant relation between the two (Giuliani et al., 2010). Specifying type of collaboration, one study shows that being a reputable researcher thanks to academic performance only matters when it comes to joint research projects, and not contract research or personnel mobility by university researchers (Schartinger et al., 2002). Others find a positive correlation between the share of a researcher's academic output published in applied journals and his or her propensity to collaborate with industry partners (Tartari & Breschi, 2012). A long resume of patent applications seems also to be a predictor of collaboration (Tartari & Breschi, 2012).

If linkages that are already established are considered, researchers with a track record of above average publications and patents seem to improve the partner firm's R&D productivity more than colleagues that perform below average (Baba, Shichijo & Sedita, 2009). The positive effect remains but is less strong if researchers excel in patenting only (Baba, Shichijo, & Sedita, 2009). Further, within established linkages, the review indicates that researchers that are part of a large tight-knit network do better when it comes to contributing to the value of patents resulting from the collaboration compared to less connected peers (Guan, J. & Zhao, Q., 2013). We infer that connectedness is positively correlated with both establishing an industry link and the quality of the collaboration output, whereas research quality is of limited importance when it comes to forming such links but more important to collaboration output quality.

Another factor influencing the propensity to collaborate is learning scope. Interest in participating in networks and linkages with industry is sparked only if the researcher believes such a link will result in learning and an exchange of relevant knowledge (Azagra-Caro et al., 2006; D'Este & Perkmann, 2011).

On the level of the university, research productivity seems to stimulate both the volume of R&D contracts and the income generated from these (van Looy et al., 2011; Caldera & Debande, 2010). This indicates that firms access information about research output and that this is central in the choice of a collaboration partner. Firms also rely on more subjective assessment of university quality, where prestigious universities tend to attract more industry partners (Wen & Kobayashi, 2001), even when these located at a distance (Laursen, Reichstein, & Salter, 2011). When it comes to matter of fact relations between universities and industry, the higher ranked universities seem to be involved in the development of more valuable innovations than lower-rank institutions (Petruzelli, 2011). Prior experience in patenting is also correlated with higher value innovations (Petruzelli, 2011). University size, measured as the number of academic staff, is another factor that seem to influence to what extent universities turn 'outwards', be it through patent applications (van Looy et al., 2011), licensing, or R&D contracts (Caldera & Debande, 2010). This is not surprising, since all else being equal more individuals can engage in more outreach activities. More interestingly, Caldera & Debande (2010) find that larger universities generate more per capita revenue from licenses and R&D contracts than smaller counterparts, suggesting that for some reason (e.g. higher quality, paying for university reputation, university bargaining power) customers are willing to pay more for licenses and contracts with larger universities. This might also be a scope effect, where a higher number of researchers raise the chances of making relevant and hence valuable

connections. One study finds that the higher the age of the university the less likely are researchers to support the idea of commercializing research results or engaging in regional development (Azagra-Caro et al., 2006).

When it comes to the industry side of the university-industry relationship, several studies find that large firms are more likely to collaborate with universities and other public research organizations than small ones (Vuegelers, & Cassiman, 2005; Segarra-Blasco & Arauzo-Carod, 2008; Fontana, Geuna, & Matt, 2006; Sáez, Marco & Arribas, 2002; Tödling, Lehner & Kaufmann, 2009; Levy, Roux & Wolff, 2009). A high level of R&D intensity increases the likelihood that a firm will establish a link with a university (Sáez, Marco & Arribas, 2002; Fontana, Geuna, & Matt, 2006; Segarra-Blasco & Arauzo-Carod, 2008; Isaksen & Karlsen, 2010) but also to approach universities in other ways, for example by locating in a university research park (Link & Scott, 2007). With a wide ranging R&D strategy comes the absorptive capacity needed to be able to benefit from knowledge produced at universities (Vuegelers & Cassiman, 2005). Benefits may materialize in various ways, the most direct being increased R&D productivity (Baba, Shichijo & Sedita, 2009) through a relative increase of patent applications and/or product or process innovations (Kodama, 2008). Firms located in the same region as the collaborating firm may benefit too, since R&D intensive firms are more likely than others to diffuse the knowledge they have acquired (Giulani & Azra, 2009). Firm staff is crucial; firms with highly educated and experienced personnel are more likely than others to link with universities (Giuliani & Arza, 2009). Also, a firm with researchers employed have the advantage of being able to bridge language and other cognitive barriers that may exist between firm staff and university researchers (Tödling, Lehner & Kaufmann, 2009) (we will return to such barriers below).

The likelihood to establish a link to a university is not only associated with input into the innovation process but also to outputs in that patenting intensity and the value of patents is correlated with establishing a link with a university (Fontana, Geuna & Matt, 2006; Petruzelli, 2011).

Finally, the review points to the fact that belonging to certain sectors increases the likelihood to collaborate with universities. High-tech sectors (Segarra-Blasco & Arauzo-Carod, 2008) such as pharmaceuticals, instrumentation, and IT are among those where firms are most prone to collaborate (Levy, Roux & Wolff, 2009). Another distinction refers to collaboration pattern. Firms belonging to the service sector are found to collaborate only sporadically and when doing so they typically form dyadic relationships with universities rather than engage in ventures that involve multiple partners (Levy, Roux & Wolff, 2009). The former grants exclusivity and is less threatening in terms of IPR infringement, whereas the latter comes close to what has been described as ‘open innovation’.

3.2 Environmental variables

The environmental variables have to do with the geographical/regional context of the collaboration, as well as its policy context, e.g. government incentives, regulation and similar. Regarding the latter, research shows that governments have the ability to stimulate collaboration positively via policy instruments that, for example, provide monetary incentives in the form of policy support for public/private R&D collaboration (Sáez et al. 2002). Cost sharing for R&D is an incentive to collaborate, and high costs of R&D are a motivation for government subsidies in this context (Vuegelers & Cassiman, 2005). Since

few articles in this review covered government incentives, legislation etc., we will focus on the geographical characteristics, some of which are amenable to being affected by government intervention and some of which are harder to steer. The R&D intensity of the region is one important factor where for example a high level of regional R&D activity makes university TTOs perform more efficiently (Siegel, Waldman, & Link, 2003). Another is the general industrial composition of the region, where high-tech intensity turns out to be positively related to collaboration and spin-off creation (Bergebal-Mirabent, Lafuente, Solé, 2013). These factors are amenable to being affected by government instruments to various degrees, specifically through R&D subsidies.

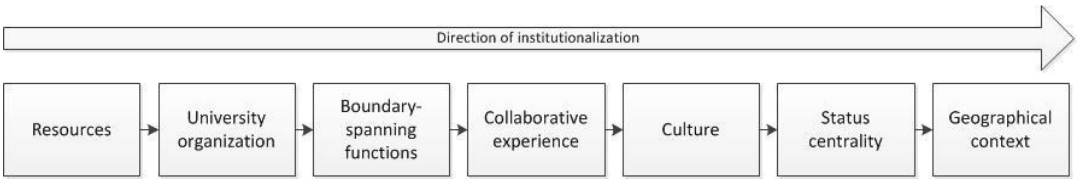
Another frequently appearing environmental factor is that of geographical proximity. Originating in the same country is a strong predictor of university-firm collaboration (Segarra-Blasco & Arauzo-Carod, 2008), and general spatial proximity between university and industry partner is consistently found to be a positive factor for contract research and consulting (Schartinger et al., 2002), commercialization of research results, and collaboration in general (Casper, 2013). Relating to the findings on boundary spanning above, geographical proximity increases the likelihood of forming intensive dyadic relationships between firms and researchers (Levy, Roux, & Wolff, 2009; see also Joly & Mangematin, 1996). This can also be referred to as 'true co-location', that is proximity that makes the paths of researchers and firms cross in various tangible ways (Locket, Kerr, & Robinson, 2008), for example through participating in innovation networks that bring actors together physically (Pérez Pérez, & Martínez Sánchez, 2003). In this sense physical rather administrative proximity matters; geographical proximity increases the likelihood that two firms located in different regions will collaborate (Scherngell & Barber, 2011).

The literature does however offer a few provisos. For example, while being located in the same country is important for the forming of licensing agreements, proximity does not have a clear positive influence on the commercial success of such licenses. Commercial success is however positively influenced by engaging the (university) inventor for further research related to the license, which is a factor that is clearly related to geographical proximity (Agrawal, 2006). One article reported that geographical distance has a positive influence on the value of the patent resulting from UI collaborations. The author suggests that this can be explained by a greater scope for truly novel innovations when actors are not part of the same spatial context (Petruzelli, 2011). Also interesting to note here is that firms located in other countries than the university are more likely than firms closer to the university to form open, multilateral relationships, often with the help of EU funding (Levy, Roux, & Wolff, 2009). Clearly this last facet opens a possibility for government influence, as does those regional network and cluster characteristics reviewed above offer some means of influencing environmental factors.

4 Towards a logic model for university-industry collaboration on innovation

We now suggest some causal inferences from the literature review in order to construct a hypothetical logic model. The proposed model considers a number of hypotheses about the operative mechanisms that link the activities and conditions along a path towards increasing levels of institutionalization of collaboration. The model (Figure 1) draws upon and complements the review results summarized in Table 1.

Figure 1 A logic model for university-industry collaboration on innovation



Starting on the left, we note that the availability, or non-availability, of resources ultimately separates the possible from the impossible – the availability of money, time or other resources is hypothesized to precede all the other factors. The first link in the model, between resources and university organization, enables the creation of an incentive system, as well as a support infrastructure for collaboration, whether it is a passive structure serving to facilitate collaboration, or active intermediation through liaison or technology transfer offices. The crafting of rules and regulations (e.g. IPR policies), also requires both time and money, e.g., to acquire new legal competencies. Lastly, resources are linked to the educational scope of a university, as polytechnic universities and medical schools typically receive more grants and more money per enrolled student than liberal arts colleges or business schools.

The second link in the model, between university organization and boundary spanning functions, represents relations between formal university structures and more or less temporary embodiments of collaboration. We hypothesize that these temporary activities largely take place within the context of formal structures. Individuals may for example be encouraged and supported to span university-industry boundaries by liaison office staff; personal relationships between researchers and industry representatives may be formed as paths are crossed in a research park or a lab, and technology transfer offices may take on the task of setting up efficient communication channels between university researchers and targeted industries. In all these cases, such activities and relations must somehow relate to the rules and regulations that are set to govern them.

The literature review showed that one of the strongest predictors of university-industry collaboration is prior experience. Therefore, the third link in our model suggests that boundary spanning creates a basis for building such collaborative experience. An industry-funded PhD-student, a company's temporary hiring of a researcher, or the transferring of research results to a firm may generate the learning processes that the literature suggests are crucial. Personal relations across the university-industry boundary create familiarity and trust, build a shared history, and an understanding of the other party's routines and expectations – all of which previous studies find to be associated with the institutionalization of collaboration.

The fourth link in the model builds on the assumption that over time, as a critical mass of individuals accumulate experience in university-industry collaboration, culture will change. As researchers and industry representatives build collaboration experience, perceptions of the other's work routines and time logic will be based on actual experiences rather than preconceptions. Working together may also settle concerns about losing control over academic freedom or trade secrets. When such obstacles are overcome, an entrepreneurial culture may develop.

The emergence of an entrepreneurial culture signals long-term, stable intentions to collaborate. The fifth link in the model hypothesizes that when an entrepreneurial culture develops, it leads to stratification among those who successfully engage in collaboration, and those who do not. The literature suggests that stratification is often explained by status centrality. The most reputable, successful, and well-connected researchers at the highest ranked universities will attract the most R&D intense firms as collaborating partners. The literature review showed that such firms, with highly educated and experienced personnel, are most likely to benefit from teaming up with university researchers.

The literature suggests that spatial proximity increases the likelihood of collaborating. As a corollary to this observation we suggest, as the last link in the model, that collaboration may maintain, reinforce or even lead to geographical proximity as collaborative relationships reach the 'final stage' of institutionalization: co-location in clusters. Universities, individual university researchers, firms, and their representatives may, as a result of a developing culture of university-industry collaboration, create and seek out fora and platforms for interaction which may reinforce such development. Well-known cases include Silicon Valley (California), Cambridge (Massachusetts), and Cambridge (United Kingdom).

5 Conclusions

This study reviews and synthesizes the literature regarding factors that stimulate university-industry collaboration on innovation. Further, we propose a model that hypothesizes possible mechanisms that leads to the institutionalization of collaboration. We recognize that ordering these the way we have can be controversial if that model is taken simply as a truthful image of reality. The temporal order of the activities and conditions in the model is based on assumptions related to their availability for intervention and amenability to change. We suggest for example that increasing resources is both faster and easier than changing culture. We also assume that increasing resources will eventually lead to culture change and the institutionalization of university-industry collaboration. Modelling this alternative scenario requires a model that includes feedback loops. Cultural change may for example cause universities to adapt their organization so that more resources, both time and funds, are freed up to enable more collaboration. Further, if collaboration is assigned high status to the extent that a local or regional 'buzz' is created, it will likely contribute to a positive spiral of researchers and firms deciding to collaborate even more. While we recognize that additional layers of complexity need to be added to this analysis, we believe that in its present form it may, at least partially describe, the development and institutionalization of collaboration in relatively immature contexts, and thus, after empirical validation, can aid in designing interventions to stimulate such collaboration.

After empirical investigation of the hypothesized links in the model it may be used to formulate collaborative strategies for universities and businesses, particularly when goal is to build capacity for such collaborations and to identify how to proceed from one's current position. It may also be applied to *ex ante* evaluations of collaborative projects and programs, in order to test the underlying program theory of such initiatives. Finally, even logic models that describe simplified versions of reality can be built upon to create more detailed sector and actor relevant models, with a higher degree of precision and local validity. Such models can be used for process evaluations and *ex post* evaluation of collaborative innovation initiatives. While the authors recognize the shortcomings of these simple models, they may nonetheless provide a starting point for future elaborations of the mechanisms operating in collaborative innovation processes.

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Appendix

Questions that guided the literature review

- Which actors are involved in collaboration (organizational roles, industry, science)?
- What type of collaboration is covered by the article?
- Which factors/actions/activities/circumstances stimulate collaboration?
- What are the outcomes of the collaboration?
- What affects whether the collaboration succeeds or fail?

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