

DOES UNIVERSITY-INDUSTRY COLLABORATION FOSTER ACADEMIC ENTREPRENEURSHIP? EVIDENCE FROM A DEVELOPING COUNTRY

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Acknowledgement: The authors acknowledge support by the São Paulo Research Foundation (FAPESP) in connection to the São Paulo Excellence Chair in innovation systems, strategy and policy established in the Department of Science and Technology Policy of the University of Campinas (UNICAMP).

Área ABEIN: Área 7 (Inovação e empreendedorismo)

JEL code: L26

Abstract

Policy decision makers and industry strategists have dedicated increased attention to initiatives that foster University-Industry Collaboration (UIC) in an environment of open innovation. The overarching goal is to enhance the capabilities/efficiencies of innovation systems, leveraging the role of universities as generators and disseminators of valuable knowledge, an issue of particular importance to developing economies. We empirically assess the extent to which institutional openness in universities towards UIC linkages affect one mode of knowledge transfer, namely the generation of knowledge-intensive spin-offs, in the context of laggard innovation systems. We use data for 462 knowledge-intensive entrepreneurial projects related to academics receiving grants from the PIPE Program of the State of São Paulo, Brazil. Additionally, we have gathered data for UIC activity (2002-2010) of 126 universities and research institutes in the affected region. We estimate both direct effects of collaboration to entrepreneurial projects and indirect effects through university patenting behavior. Results suggest that the quality of linkages is a stronger predictor of both types of university entrepreneurship than the quantity of connections.

Keywords: Knowledge-Intensive Entrepreneurship; University-Industry Collaboration; Open Innovation; Academic Spin-offs.

Resumo

Tomadores de decisão em políticas industriais têm crescentemente dedicado atenção a iniciativas que promovem a interação universidade-empresa (IUE). O principal objetivo é alavancar as capacidades dos sistemas de inovação, a partir da concepção de que as universidades geram e disseminam conhecimento, questão essa de importância particular para as economias em desenvolvimento. Assim, neste trabalho buscou-se empiricamente avaliar em que medida a abertura institucional das universidades em relação a IUE afeta a geração de *spin-offs* acadêmicos intensivos em conhecimento no contexto dos sistemas de inovação imaturos. Para isso, foram utilizados dados referentes a 462 projetos de empreendedorismo intensivo em conhecimento relacionados a acadêmicos que receberam recursos do Programa PIPE do Estado de São Paulo, Brasil. Além disso, utilizaram-se dados referentes às interações entre empresas e 126 universidades e institutos de pesquisa. Foram estimados os efeitos diretos da interação nos projetos de empreendedorismo, bem como os efeitos indiretos da interação nas atividades de patenteamento das universidades. Os resultados sugerem que a qualidade das interações é um preditor de maior relevância do que a quantidade de ligações em ambos os tipos de empreendedorismo universitário (*spin-offs* e patentes).

Palavras-chave: Empreendedorismo intensivo em conhecimento; Interação Universidade-Empresa; Inovação Aberta; *Spin-offs* acadêmicos.

1. Introduction

It is widely accepted that universities can be influential agents in the context of the knowledge-intensive economy (Czarnitzki et al., 2016; Etzkowitz & Leydesdorff, 2000). The impact of their

engagement is likely to be felt at regional and national levels (Brown, 2016; Padilla-Meléndez & Garrido-Moreno, 2012). This perception has received substantial attention from decision makers in the public and private sectors trying to foster closer connections between academic institutions and businesses in an environment increasingly defined by open innovation (Boh et al., 2015; Looy et al., 2011; Pfirrmann, 1998; Lee, Lim & Tan, 1999). For instance, the weight of industrial funding of academic research has grown (Gulbrandsen & Smeby, 2005) in the last decades, pinpointing the rising relevance of university-industry collaboration (UIC) for innovation.

The overarching goal is to strengthen the capabilities/efficiencies of innovation systems, leveraging the role of universities as generators and disseminators of valuable knowledge. Some of the main conduits for these linkages are related to knowledge transfer activities, such as training, consultancy, R&D and academic spin-offs (Brown, 2016). The focus of this article is on the latter, i.e., the generation of new knowledge-intensive ventures as a byproduct of the increased proximity between firms and academia.

An open question is whether such interactions generate substantial learning effects to transform academic institutions into more active generators of knowledge-intensive entrepreneurship (KIE)¹. This subject is not new: the generation of academic spin-offs has served as performance indicator in many institutions since the 1990's (Bonaccorsi & Piccaluga, 1994). Notwithstanding these aspects, and the trend of universities becoming increasingly entrepreneurial (Etzkowitz, 2004), there is a large variability among universities in terms of start-up generation (Di Gregorio & Shane, 2003). In addition, the relationship between research collaboration and spinoffs has not been adequately addressed in the literature and results are inconclusive.

Even lesser attention has been paid to the case of developing countries, which face several constraints in terms of innovation-oriented entrepreneurship (Lederman et al., 2014). These countries not only have limited levels of human capital, they often find it concentrated in universities (Abereijo, 2015). Moreover, weak innovation systems in such countries are characterized by weak, inefficient ties between agents giving additional importance to UIC externalities that might translate into further academic entrepreneurial capabilities. We ask *to what extent does institutional openness in universities towards UIC linkages affect the generation of knowledge-intensive spin-offs in the context of laggard innovation systems?*

Originally the target of negative prejudice by the research community, academic entrepreneurship became a legitimate activity (Stuart & Ding, 2006), extending the reach of university contributions from traditional forms of technology transfer to companies to a direct vector of economic development (Di Gregorio & Shane, 2003). Universities are increasingly perceived as sources of innovation-driven entrepreneurship (Krabel & Mueller, 2009; Landry et al., 2006), even though this does not translate into a substantial body of work in terms of investigations concerning research-driven academic entrepreneurship (Goel & Grimpe, 2012).

We appraise academic KIE in the State of São Paulo, Brazil. We use data for 462 KIE projects related to academic personnel (professors, lecturers, researchers, and students) that received grants from the PIPE Program from the São Paulo Research Foundation. This program supports innovative initiatives in small enterprises and it resembles in structure and objectives the Small Business Innovation Research (SBIR) program in the United States (Salles-Filho et al., 2011).

Additionally, we have gathered data from the Brazilian National Council for Scientific and Technological Development (CNPq) Research Group Directory Census, with biennial information available from 2002 to 2010, covering 126 universities and research institutes within the area of investigation. This allowed us to check for three differential aspects of UIC: “Density” (share of cooperating research groups within a university), “Width” (average number of cooperating firms per research group), and “Depth” (object of the collaboration). This represents a new and extended way of assessing the issue of UIC from a diversified point of view, offering more detailed results on

¹ Hirsch-Kreinsen and Schwinge (2014) define KIE as an entrepreneurial activity involving the market exploitation of new opportunities, which can be carried out by individuals or established organizations. These ventures are likely to have significant impacts upon economic growth, social welfare and wealth creation (Beckman et al., 2012).

the topic. Negative binomial models for count data were applied to direct and indirect (via patenting activity) effects of UIC upon academic KIE.

Controlling for the Knowledge Transfer Infrastructure, Intellectual Environment, and Entrepreneurial Traits of projects, results indicate that the “density” of interactions has a detrimental effect on academic KIE, while “width” has minor effects. On the other hand, the quality of collaboration (“depth”) seems to be a key ingredient for the generation of desirable externalities. The low propensity of the analyzed innovation system to establish high-quality, R&D-oriented interactions between academia and firms may then negatively influence the emergence of academic KIE from this perspective. Could this also be extended to other countries in similar stages of development?

The remaining of the article is structured as follows: Section 2 introduces some key aspects of academic KIE. Section 3 reviews previous research on UIC and academic entrepreneurship, as well as it sets our research hypotheses. Section 4 makes a description of the sample. Section 5 states the analytical rationale. Results can be found in Section 6, and Section 7 concludes with some final remarks.

2. University-Industry Collaboration as a Conduit for Academic Knowledge-Intensive Entrepreneurship: Hypotheses

From universities’ perspective, academic spin-offs are an important vehicle for university research commercialization (Landry et al., 2006; Zucker et al., 2002), allowing basic research to reach out to industry (Perkmann & Walsh, 2007). The notion of the university as a support entity for evolutionary processes of entrepreneurial ecosystems is not new (Dorfman, 1983). This perception rests on the institutional role of universities as sources of ideas, manpower, and entrepreneurs themselves. In the same vein, Etzkowitz (1998) puts the university and academic researchers as fundamental agents of innovation systems through knowledge transfer and entrepreneurial² activities.

But the entrepreneurial university does not only generate academic spin-offs. Such institution is also prone to cooperate closely with industrial partners (Etzkowitz, 2004). Incentives for UIC are clear: firms can enhance their innovative potential and reduce R&D costs, while accessing new knowledge in scientific and technological fields (Agrawal, 2001). This is basically what makes academic institutions important partners for firms’ open innovation strategies (Tether, 2002). On the other hand, universities can have access to external funding and boost research productivity (Arza, 2010).

As it turns out, universities have increasingly participated in open innovation activities, playing a central role in these interactions (Striukova & Rayna, 2015). This can be largely attributed to a decline in innovation self-sufficiency as a function of agents’ needs for external sources of knowledge, and cost and risk sharing (Chesbrough, 2003). Consequently, within the dynamics of open innovation, U-I links play a central role in innovation processes (Perkmann & Walsh, 2007; Roshani et al., 2015).

However, this tells only part of the story. It is well established that, at least for developed economies, UIC serves its purpose and it widens the reach of academic knowledge towards innovation systems. However, we propose that these activities generate learning and networking externalities within the academic context, planting the seed for increased entrepreneurial capabilities. This could help explaining why UIC is closely related to the emergence of academic entrepreneurs (Abreu & Grinevich, 2013). Such argument is in line with the Triple Helix approach, which states that a closer connection between universities, industry and government improves overall conditions for innovation (Etzkowitz, 2004). Hence, outcomes of UIC could be felt not only by incumbents’ evolving innovation capabilities, but also by the emergence of new players.

The mechanisms through which these learning effects are somewhat simple. First, we have that the historical cognitive distance between university and industrial worlds may hamper academic

² Etzkowitz (1998) makes reference to the figure of the "entrepreneurial scientist".

entrepreneurship from getting into practice (Colyvas et al., 2002). This is not only a condition related to technical aspects of academic research, but rather it is strongly related to the relational character of entrepreneurship. Starting a new venture (particularly an innovation-driven firm) involves the formation of networks by the nascent entrepreneur and depends on existing levels of trust among agents (Stam, 2009). Precisely for this reason some authors have put strong emphasis on what is called "entrepreneurial support networks", i.e., business agents that offer complementary resources, relevant information on business dynamics and external sources of support and services to the activity of entrepreneurial ventures (Birley, 1985; Kenney & Patton, 2005).

In line with these propositions, literature on academic spin-offs provides strong support for the assumption that business networks matter for the emergence of successful academic entrepreneurship (e.g. Hayter, 2016; Lockett et al., 2003; Moutinho et al., 2014; Nicolaou & Birley, 2003; Shane & Stuart, 2002; Walter et al., 2006). Additionally, U-I linkages facilitate the generation of academic spin-offs through the provision of a better understanding of market potential and development of adequate business models (Looy et al., 2011). In its turn, UIC has the potential of bringing beneficial impacts upon academic researchers' social networks, providing a bridge from academia to market (Landry et al., 2006; Landry et al., 2007; Padilla-Meléndez & Garrido-Moreno, 2012).

Therefore, some authors find close ties to industry to have positive influences on levels of academic entrepreneurship (Krabel & Mueller, 2009). Perkmann et al. (2013) find that academic engagement with business firms is often associated with research commercialization via academic spin-offs or licensing agreements. Results from Arvanitis et al. (2008) conclude that access to industrial knowledge and funding functions as a driver of entrepreneurial propensity in universities (Arvanitis et al., 2008). Other authors have achieved similar outcomes, where the level of R&D funding from industry in a university leverages potential for spin-off generation (Gulbrandsen & Smeby, 2005; Landry et al., 2006; O'Shea et al., 2005; Powers & McDougall, 2005; Rasmussen et al., 2014). Most of these analyses are focused on cases taking place within the United States and other developed economies, but Abereijo (2015) has found analogous evidence for developing countries.

Based on this conceptual and empirical body of work, our expectation is that more "open" academic environments for UIC will lead to an institutional context that offers higher levels of relational capital, market awareness and business orientation for academic entrepreneurs. Our first research hypothesis, thus, takes the following structure:

H1. Universities that establish higher aggregate levels of University-Industry Collaboration will be endowed with stronger capabilities in terms of generating knowledge-intensive academic spin-offs.

Nonetheless, we must recognize that results leading to this hypothesis do not go unchallenged. For example, by investigating the proportion of universities' research that was sponsored by industry, Di Gregorio and Shane (2003) do not find significant effects of increased UIC in the entrepreneurial propensity of academics. Lee (2000) finds that only a minority of academics perceive UIC as a source of business opportunities. Under a similar perspective, Landry et al. (2006) suggest that UIC may bind academic researchers to directly transfer research outputs to firms, negatively influencing their entrepreneurial propensity.

Another reasonable explanation for this variability in research findings is that not all collaborations are made alike. Therefore, the mere analysis of amount of UIC as a conduit to academic KIE may be misleading. The key element in these dynamics is the object of interactions³, since the knowledge exchange content can be highly representative of the learning curves that are at play. Arza (2010) proposes that proactive, strategic behavior of firms is much more likely to lead to the emergence of academic entrepreneurship. For Thursby and Thursby (2002), high-quality engagement is mainly oriented towards R&D interactions, but not routine training and consulting

³ Illustratively, Schartinger et al. (2002) classify types UIC into four groups: i) joint research; ii) contract research; iii) personnel mobility; and iv) training activities.

activities, where only the first functions as a driver of universities' patenting and entrepreneurial trends.

This is probably because University-Industry links with high relational involvement (joint production of knowledge, innovation and research) are the ones that represent a true network-based mode of innovation (Perkmann & Walsh, 2007). In this case, the expectation of positive externalities within the academic entrepreneurial environment must take into account how relationships unravel. This poses a difficulty for academic KIE in immature innovation systems, where UIC is fundamentally based on consultancy and training activities (Arocena & Sutz, 2001; Fernandes et al., 2010). These linkages are often representative of operational (rather than strategic) collaborations, with core focus on cost savings (Rapini et al., 2009). In developed economies, instead, increase in companies' knowledge base has been reported as the main reason behind U-I partnerships (Caloghirou et al., 2001). As a result, the generation of spin-offs is not a common outcome from UIC in developing economies (Fernandes et al., 2010). These discussions lead us to propose the following research hypothesis:

H2. Universities that establish a higher quality of University-Industry Collaboration will be endowed with stronger capabilities in terms of generating knowledge-intensive academic spin-offs.

The next sections are focused on presenting and discussing the empirical approach related to both of our research hypotheses, as well as discussing additional control variables and specifications of econometric models.

3. Data Description

Our data sample is from 126 higher education institutions (HEIs) and research institutes in the State of São Paulo, Brazil⁴. These organizations were included in the Census from the Brazilian National Council for Scientific and Technological Development (CNPq) Research Group Directory, with biennial data available from 2002 to 2010 (5 periods – more recent versions of the census have not been made public). Institutions did not necessarily participate in every census, thus configuring an unbalanced panel data structure.

For all of these institutions we have information on research groups that have established cooperative projects with industry, with how many companies each institution has interacted with, and the content of the collaboration (see Table 1 for an overview of the UIC context according to our sample). These data allow us to represent the degrees of UIC that make up our proxy of university openness. While there is no guarantee that the dataset presents a comprehensive picture of the entire population of research groups and their respective collaborations with industry – the census is based on self-reports by research groups' leaders – the fact that updated information on these groups is required for accessing public grants gives us confidence that the data closely resembles the actual situation of UIC in the State of São Paulo.

Table 1. UIC overview in the State of São Paulo, Brazil.

Census	Research Groups	Interacting Research Groups	Cooperating Firms ⁵	R&D-oriented Collaborations	Training and Consultancy-oriented Collaborations	Total ⁶	% of R&D-oriented Collaborations
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⁴ It is important to underscore that even though the vast majority of institutions in our sample consist in universities, there are also several research institutes. Following the extant literature on UIC, we adopt a flexible view of the term "university" to also include these additional cases. Hence, whenever we refer to UIC (or universities as a whole), research institutes are part of the discussion (Cohen et al., 2002; Zawislak & Dalmarco, 2011).

⁵ Cooperating firms are computed according to each established UIC. Hence, if a company cooperates with several groups it will be counted on each one of these links.

⁶ The number of collaborations exceeds the number of companies and research groups because each company can establish up to 3 different kinds of UIC agreements with each group.

2002	4,338	253	511	752	359	1111	67,69
2004	5,540	464	901	1359	599	1958	69,41
2006	5,678	527	985	1413	644	2057	68,69
2008	5,908	572	1,276	1545	650	2195	70,39
2010	6,314	745	1,596	1809	977	2786	64,93

The other key aspect of this research concerns the emergence of academic knowledge-intensive entrepreneurship. The grants of the PIPE program (Innovative Research in Small Enterprises) are used as a proxy for KIE activity in the State. This initiative is managed by the São Paulo Research Foundation (FAPESP) and it subsidizes entrepreneurial projects with high levels of knowledge-intensity and innovative potential. It was created in 1997, inspired by the Small Business Innovation Research (SBIR) program in the United States. After a careful analysis of information from projects and entrepreneurs, 462 PIPE projects could be associated with academic entrepreneurs for the period 2002-2011 (out of a total of 730 projects). Institutional affiliation includes both academic personnel (faculty and researchers) and temporary staff (students and post-docs). This is justified by the perspective that graduate students and post-doctoral researchers are important agents in the context of academic startups (Boh et al., 2015).

We allow for a lag between entrepreneurial activity and its institutional correspondence in terms of UIC. This was done in two steps: first, institutional affiliation was considered valid up to two years before the start of the project. Second, KIE projects were associated with each wave of the Research Group Census until the next census took place. Since the census took place every two years, we ascribed academic KIE projects to previous UIC data. Hence, the 2002 UIC information is associated with entrepreneurial projects taking place from January, 2002 until December, 2003. This procedure is valid for every period in the sample, explaining why KIE data goes until the end of 2011 while the last UIC census is available for 2010⁷.

We recognize that this dataset represents only a fraction of the academic KIE scenario in the State of São Paulo. However, this source provides the opportunity of identifying the year of entrepreneurial projects' start, as well as identification of entrepreneurs. This allows us to gather complementary data on institutional affiliation, field of knowledge, and professional and academic backgrounds of individuals (Curriculum Lattes Database)⁸. Furthermore, it offers an interesting source of "certified" knowledge-intensive entrepreneurs selected after careful expert review.

Further variables of interest are outlined in Table 2. We have assigned each variable to a particular block. Besides the core dependent variable (KIE_Projects), four other blocks are added to the analytical exercise, namely: U-I relationships, Knowledge Transfer Infrastructure, Intellectual Environment, and Entrepreneurial Traits. This particular set of variables follows suggestions and similar approaches undertaken by several authors (e.g. Arvanitis et al., 2008; Audretsch et al., 2016; Dietz & Bozeman, 2005; Di Gregorio & Shane, 2003; Goel & Grimpe, 2012; Landry et al., 2006; Looy et al., 2011). Descriptive statistics of analytical variables are shown in Table 3.

Table 2. Analytical variables.

Code	Block	Description	Source
KIE_Projects	Dependent	Number of PIPE projects granted to a researcher affiliated with a university in the State of São Paulo in a given period. Affiliations were considered for people involved with universities (as students, researchers or faculty) up to 2 years before PIPE grants. Multiple affiliations were assigned according to number of hours worked at each institution.	São Paulo Research Foundation

⁷ Additional possibilities of time lags are taken into account in econometric models, aiming at identifying longer-term connections between university openness and academic entrepreneurship.

⁸ This database is maintained by the Brazilian Council for Scientific and Technological Development and registration is required for scholars (professors, researchers and students).

Density		Share of research groups that have performed interactions with industry. Only formal groups registered at the National Directory of Research Groups are considered.	Brazilian Council for Scientific and Technological Development - Census data available from the Research Group Directory
Width	U-I Relationships	Average number of cooperating firms per research group that has performed interactions with industry.	
Depth		Dummy variable. It takes the value of 1 whenever there is a predominance of UIC based on R&D ("deep" relationships). It takes the value of 0 otherwise (predominance of training activities, consulting and supply of materials for research activities).	
Entrep_Infra	Knowledge Transfer Infrastructure	Dummy variable. It takes the value of 1 whenever the university-year has (or is formally affiliated with) a business incubator and/or science park; 0 otherwise.	Institutional websites
TTO		Dummy variable. It takes the value of 1 whenever the university-year has (or is formally affiliated with) a technology transfer office; 0 otherwise.	
Res_Eminence		Dummy variable. It takes the value of 1 whenever the university-year is above the 75th percentile of the sample in terms citations (Web of Science) per registered research groups; 0 otherwise.	Web of Science
Res_Intensity	Intellectual Environment	Dummy variable. It takes the value of 1 whenever the university-year is above the 75th percentile of the sample in terms of total publications (Web of Science) per registered research groups; 0 otherwise.	
Patents		Domestic patent applications associated with each university-year of the sample.	
PhD%		Share of KIE projects assigned to a university-year that are granted to PhDs.	Lattes Platform (Academic CVs database)
Prof_Exp%	Entrepreneurial Traits	Share of KIE projects assigned to a university-year that are granted to entrepreneurs with previous non-academic professional experience.	
STEM%		Share of KIE projects assigned to a university-year that are belong to STEM fields.	

The set of variables in Table 2 is arguably more appropriate for the study of university openness and academic entrepreneurship than what has been used elsewhere (usually share of university research funded by industry). For instance, we are able to identify the object of interaction (variable Depth), an issue that is likely to affect the outcomes of collaboration (Fernandes et al., 2010). Moreover, "Density" and "Width" allow assessing the extent of university association with industry and the different companies that collaborate with research groups. These aspects offer the possibility of understanding different scopes of UIC and the corresponding effects on academic entrepreneurship.

Table 3. Sample description.

Variable	Obs.	Mean	S.D.	S.D. within Universities	S.D. between Universities	Min.	Max.
KIE_Projects	630	0.73333	3.838	18.581	34.699	0	53
PhD%	630	0.12738	0.31928	0.26266	0.2167	0	1
Prof_Exp%	630	0.1267	0.31974	0.27776	0.20168	0	1
STEM%	630	0.12363	0.3146	0.2638	0.20855	0	1
Density	485	0.092218	0.1456	0.082218	0.147	0	1
Width	485	10.122	14.044	0.91026	11.207	0	86.667
Patents	630	27.762	14.954	4.886	14.346	0	170
Variable	Observations		Frequency (0)		Frequency (1)		
Depth	485		267 (55.1%)		218 (44.9%)		
TTO	630		543 (86.2%)		87 (13.8%)		
Entrep_Infra	630		555 (88.1%)		75 (11.9%)		

Res_Eminence	630	505 (80.2%)	125 (19.8%)
Res_Intensity	630	509 (80.8%)	121 (19.2%)

Another characteristic of our dataset is the significant concentration of KIE projects within some key institutions. 71.6% of the total number of 462 PIPE Projects included in the dataset belong to only four universities: University of São Paulo (USP), University of Campinas (UNICAMP), State University of São Paulo (UNESP), and Federal University of São Carlos (UFSCAR). All of these institutions have multiple campuses, spreading their geographical influence across the State. A further evaluation of the sample also helps shedding light on concentration: Gini coefficients for each university-year observation of KIE projects ranges between 0.92 and 0.94.

4. Models and Estimations

Estimations of econometric models are developed in a two-stage structure (Figure 1 illustrates a simplified version of the approach). The first stage aims at checking for direct connections between KIE_Projects and the remaining analytical blocks (U-I Relationships, Knowledge Transfer Infrastructure, Intellectual Environment, and Entrepreneurial Traits). For these estimations, each block is added at a time cumulatively. Because the timeframe may render misleading results due to longer-term relationships between the U-I Relationships block and the dependent variable, an additional set of estimations is provided for lags of these variables in a complete version of the model (t-1 and t-2). This procedure is consistent with the idea that university openness might generate internal capabilities that take time to mature and become actual KIE projects able to receive grants from external sources (such as the case for PIPE projects).

The second stage of the approach consists in an indirect form of evaluating predictors of academic KIE through its impacts on universities' patenting behavior (assuming that patents may translate into other forms of technology transfer, such as entrepreneurship). If on the first set of models Patents was inserted within the Intellectual Environment Block, now it assumes the role of dependent vector. We do so based on an expectation that this variable performs a positive and significant role as predictor of KIE_Projects in the first stage, and that U-I collaboration may lead to stronger patenting activity, provided that patents represent a key form of intellectual property management in knowledge transfer activities (Zucker & Darby, 2001; Salimi et al., 2015). If this is the case, even the lags introduced previously may fail to capture this indirect channel of impacts arising from stronger and deeper UIC. In this stage, since KIE projects are not part of the analysis, the Entrepreneurial Traits block is dropped from estimations.

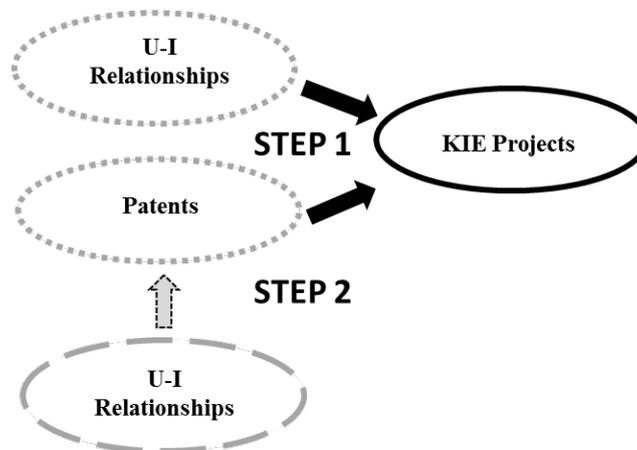


Figure 1. Analytical rationale of the two-stage approach.

Econometric procedures applied to the sample, considering the dependent variable in both steps outlined above, is that of Generalized Estimating Equations (GEE) for count data. This approach is suitable for our analysis due to the structure of the dependent variables, the possibility of

autocorrelation in standard errors, the large share of universities with no KIE projects over time, and the unobserved unit-level heterogeneity that can influence the emergence of entrepreneurial activity. Tests for over-dispersion suggested the inadequacy of Poisson estimations for all models, thus warranting the use of Negative Binomial estimations.

5. Results

Following the structure of econometric estimations, results of step 1 (KIE_Projects as dependent variable) are offered in Table 4 and those of step 2 can be found in Table 5. Initially, five models are analyzed, adding predictor blocks one by one. Firstly, it is fundamental to check the validity of our two-step analytical procedure by turning to the evaluation of the variable Patents. As it can be seen in Table 4, patenting output functions as a solid, significant predictor for entrepreneurial activity, even though its impact is not very large⁹. It is thus reasonable to accept that our analytical rationale is valid for this particular sample.

Table 4. Negative Binomial Models 1-5 (Step 1 - KIE_Projects dependent).

Block		Model 1	Model 2	Model 3	Model 4	Model 5
U-I Relationships	Density	-2.409** [1.169]	-.060 [.891]	-3.068*** [1.141]		
	Width	.063 [.108]	.128 [.079]	.153* [.086]		
	Depth	1.443*** [.323]	.652** [.293]	.271 [.317]		
Knowledge Transfer Infrastructure	Entrep_Infra	2.233*** [.270]	1.440*** [.234]	1.442*** [.240]	1.165*** [.234]	.987*** [.249]
	TTO	1.317*** [.285]	.385 [.252]	-.067 [.238]	.243 [.235]	.193 [.271]
Intellectual Environment	Res_Eminence		.658** [.284]	.831*** [.290]	1.115*** [.317]	1.076*** [.401]
	Res_Intensity		.719** [.291]	.023 [.317]	-.131 [.333]	.014 [.425]
	Patents		.017*** [.003]	.013*** [.002]	.012*** [.002]	.013*** [.001]
Entrepreneurial Traits	PhD%			1.136*** [.322]	.856*** [.322]	1.053*** [.326]
	Prof_Exp%			1.480*** [.310]	1.320*** [.324]	.827** [.356]
	STEM%			1.509*** [.293]	1.593*** [.302]	1.572*** [.313]
U-I Relationships (with lags)	Density t-1				-3.405*** [1.286]	
	Density t-2					-2.752 [1.832]
	Width t-1				.094 [.088]	
	Width t-2					.293*** [.105]
	Depth t-1				.601* [.321]	
	Depth t-2					.097 [.315]
Time dummies	Dummy 2002-2003	1.403*** [.455]	1.367*** [.404]	1.465*** [.422]		

⁹ Some caution must be taken for the appropriation of estimations in Models 6-9. Patents might also be somewhat associated with institutional size, and in the absence of a proper size control it is difficult to disentangle these effects. Nonetheless, other variables also help to control for size effects (Res_Intensity and Entrep_Infra), thus helping to control for potential instabilities in the model.

is associated with negative impacts – even in model 4 where it is analyzed with a 1-year lag. The rather large coefficients of Density can be partially explained by the structure of this variable (a ratio). On the other hand, in step 2 where university patenting activity is the dependent variable, Density does not enter any specification (Models 6-9) as a significant predictor.

Hence, as a first diagnostic, we find no evidence that the extent of industry collaboration of university research groups has positive effects on academic entrepreneurial activity. More than that, in some cases it seems to be related to decreasing levels of KIE. One can think of this as introductory evidence into the importance of the qualitative aspects present in UIC: more does not necessarily translate into better (at least in terms of KIE activity and patenting behavior). Although contrary to our expectations, this result is not entirely surprising. Using just the level of university research funding by industry to proxy UIC, Di Gregorio & Shane (2003) also reach similar conclusions. Nonetheless, the presence of significant and negative signs in some coefficients for this variable point towards the possibility of decreasing returns to collaboration, where extensive interactions with industry may have detrimental effects on researchers activities related to scientific knowledge production (in favor of applied technological problems) (Arza, 2010) eventually hampering science-based, knowledge-intensive entrepreneurial endeavors.

Width which represents the average number of firms involved in UIC projects, is significant in Model 3, and obtains increasing statistical validity when lagged by two periods (Model 5) while its coefficient almost doubles. This variable is found to be a positive and significant predictor of patenting activity in model 7. This might indicate some sort of structural, long-term impacts of UIC upon academic KIE activity, leading to non-immediate learning effects of universities' association with industry. This would happen via direct (through a lagged version of the indicator) and indirect (current effect on patents) relationships. Nonetheless, there is a lack of robustness in the results for Width, allowing these discussions to be merely suggestive, and contributing only to a partial acceptance of our first research hypothesis.

Our last variable of interest for the specification of U-I Relationships is Depth. Contrary to the other two variables, this one incorporates a much more qualitative view of the collaboration phenomenon, since it stands for the content (or object) of the interaction. In this case, the significance of the variable is more uniform across specifications of models (models 1, 2, 4, 6, 7 and 8), although with decreasing relevance for lagged observations in step 1 analysis. This is interesting as it complements the perception of openness level with an idea of openness quality. Although these results are not entirely robust, they suggest that our second hypothesis can be accepted – as well as granting interest in future examinations of these differential aspects of UIC.

The remaining variables (controls) included in the models offer interesting insights. The Knowledge Transfer Infrastructure block plays an important role in shaping the environment for academic KIE in this sample. This is particularly true for the case of university science parks and business incubators (Entrep_Infra), which is strongly and robustly related to the dependent variables in both steps 1 and 2¹⁰. Technology Transfer Offices (TTO) are not very good at predicting KIE activity directly, but the effect on patenting behavior is noticeable (and even larger than those found for physical infrastructure). The results for TTOs are partly in line with previous findings that do not find strong support for these offices in terms of technology transfer (Czarnitzki et al., 2016). In contrast to these studies we find TTOs positively related to patenting activity that closely relates to their remit.

Variables included in the Intellectual Environment block provide unstable results. Patents is included as a predictor only in step 1, and, as already pointed out, it is robustly positive and significant. On the other hand, Res_Eminence (as a proxy for institutional impact) is only positive and significant in models 1-5 (KIE projects). In step 2 it loses its statistical significance and turns negative. In contrast, Res_Intensity is weakly associated with KIE_Projects but plays a significant and positive role as a predictor for the generation of patents. In other words, university strength in

¹⁰ This variable also functions as a proxy for institutional size, as most science parks and incubators are associated with large universities.

quality publications is positively related to KIE projects whereas strength in terms of overall quantity of publications is positively related to patents.

Lastly, project-specific variables (Entrepreneurial Traits block) are only included in the first step of estimations. In all cases, as expected, the share of PhDs, STEM projects and academic with previous non-academic professional experience are positively and significantly related to KIE activity. While the share of PhDs and STEM projects might have their significance affected by the selection characteristics of the PIPE projects, it is important to notice that the importance of earlier business-oriented activity by scholars might pose some implications for entrepreneurial policy in Brazil. Under current regulations, professors and graduate students at public universities (those ones with the highest concentration of the most academic KIE projects in our sample) can find it very hard to coordinate academic and non-academic positions.

6. Concluding Remarks

This article has dealt with the dynamics of academic KIE emergence in a laggard innovation system as a function of institutional engagement in University-Industry Collaboration. We departed from two hypotheses related to the idea of learning effects (externalities) arising from UIC within academic environments, dealing with both direct effects on knowledge-intensive entrepreneurial (KIE) projects and indirect effects through patenting behavior. Results suggest that the quality of linkages (hypothesis 2) is a stronger predictor of entrepreneurship than the level (or quantity) of connections (hypothesis 1).

To dig a little deeper into these issues, some contextualization is necessary. Data from the 2011 Brazilian Innovation Survey (PINTEC) show that, in the State of São Paulo, about 2.6% (1,119 out of 43,469 responding companies) of the sample develop interactions with universities and research institutes. More importantly, only about half of these firms (52.6% or 589 companies) establish R&D-oriented activities (instead of technical, training and consulting forms of cooperation). Additionally, three quarters of companies that have implemented innovations (75.7% of 14,787 firms) believe UIC to be of little or no importance for innovative processes. These data, along with recent trends are presented in Appendix I. Although throughout the 2000's the numbers of companies establishing UIC has grown, this does not translate into neither a relative evolution of firms involved in higher quality (R&D-oriented) partnerships with universities or research institutes, nor into academia being perceived by corporations as a critical player for open innovation strategies. This descriptive outline of the regional environment for UIC in the area under study has implications for the evaluation of our econometric results.

First, it helps explaining why the “density” and “width” of relationships have mixed and non-robust outcomes for estimations. UIC does not seem to be a priority for companies embedded in this innovation system. This is likely to affect the objectives of collaboration and, hence, the quality of knowledge exchanges. Second, and complementary, the “depth” of UIC seems to be behind most of the positive impacts that university openness can offer in terms of academic KIE (directly and via patenting behavior). This may be considered as problematic for the entrepreneurial environment in a developing country context due to the less R&D intensive U-I interactions that may negatively affect the universities' ability to spawn new knowledge-intensive activity.

Other findings of interest include the results over the importance of Technology Transfer Offices in patenting but relative unimportance in the entrepreneurial process. It is important to stress that the institutionalization of TTOs is relatively recent in Brazil since most of them have been created as a response to the 2004 Innovation Law, which, among other things, regulates UIC. Thus, it is possible that the examined TTOs had not yet established sufficient levels of business development capabilities necessary to promote higher levels of academic spin-offs (Lockett & Wright, 2005).

A careful look at our data and results clearly indicates a bifurcation of the university system in the State of São Paulo. The higher education system there is strongly oriented towards training and teaching at undergraduate levels. By and large, universities in this group are not engaged in KIE. On the other hand, those few universities that produce impactful scientific and technological

research, understand entrepreneurship as part of their mission, and create/associate with science parks and business incubators, present consistently better results in terms of academic KIE.

Our research is subject to limitations. The clearest limitation has been the lack of data on various dimensions of interest, particularly for KIE activity. Since we are using data from a specific program, we are not covering the population of academic KIE but a subset of it. To justify our choice, it is important to bear in mind that PIPE grants give us quality information on what is supposed to be KIE (since projects are evaluated and selected according to their innovative content) and also tell us who the responsible entrepreneur is. This is a fundamental link to access their curriculum for institutional affiliations – going back to the time the project was launched – and professional and academic traits, both fundamental for our models.

Several future research avenues arise from the findings reported in this article. First, it would be interesting to get a better handle on the link between academic patenting and university spin-offs. Second, better understanding of whether KIE springing directly from university-industry collaboration shows different development cycles and rates of success (following the literature in section 3) would really boost policy arguments in that direction. Lastly, going beyond the State of São Paulo to replicate results in a broader set of developing nations/regions would add validity to the general argument.

Appendix I. Brazilian Innovation Survey (PINTEC): UIC trends in the State of São Paulo

PINTEC	Total Companies in the Survey	Companies with Collaborative Processes	Companies with UIC	UIC Object (Only Companies with UIC)		Cooperation Importance (Companies with Collaborative Processes)		
				R&D activities	Others	High	Medium	Low/No relevance
2003	29,650	347 (1.17%)	219 (0.74%)	151 (69%)	68 (31%)	85 (24%)	54 (16%)	208 (60%)
2005	31,990	933 (2.92%)	331 (1.03%)	159 (48%)	171 (52%)	141 (15%)	93 (10%)	700 (75%)
2008	36,549	1,549 (4.24%)	620 (1.70%)	324 (52%)	297 (48%)	288 (19%)	169 (11%)	1,092 (70%)
2011	43,469	2,749 (6.32%)	1,119 (2.57%)	589 (53%)	530 (47%)	410 (15%)	258 (9%)	2,080 (76%)

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