ARE RESEARCHERS DELIBERATELY BYPASSING THE TECHNOLOGY TRANSFER OFFICE? AN ANALYSIS OF TTO AWARENESS

Annelore Huyghe
Australian Centre for Entrepreneurship Research
Queensland University of Technology
2 George Street GPO Box 2434
Brisbane QLD 4001
Australia
Email: annelore.huyghe@qut.edu.au

Mirjam Knockaert
Ghent University
Tweekerkenstraat 2
9000 Ghent
Belgium
and University of Oslo, Norway
Email: mirjam.knockaert@ugent.be

Evila Piva
Department of Management, Economics and Industrial Engineering
Politecnico di Milano
Piazza Leonardo da Vinci 32
20133 Milan
Italy
Email: evila.piva@polimi.it

&

Mike Wright
Imperial College Business School
46 Exhibition Road
London SW7 2AZ
United Kingdom
and Ghent University, Belgium
Email: mike.wright@imperial.ac.uk

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ABSTRACT

Most universities committed to the commercialization of academic research have established technology transfer offices (TTOs). Nonetheless, many researchers bypass these TTOs and take their inventions directly to the marketplace. While TTO bypassing has typically been portrayed as deliberate and undesirable behavior, we argue that it could be unintentional as many researchers may simply be unaware of the TTO's existence. Taking an information-processing perspective and using data on 3,250 researchers in 24 European universities, we examine researcher attributes associated with TTO awareness. Our evidence confirms that only a minority of researchers are aware of the existence of a TTO at their university. TTO awareness is greater among researchers who possess experience as entrepreneurs, closed many research and consulting contracts with industry partners, conduct research in medicine, engineering or life sciences, or occupy post-doctoral positions. Policy implications of these findings are discussed.

Keywords: TTO Awareness, TTO Bypassing, Information-processing, Knowledge Corridor, Entrepreneurial Universities

JEL-codes: L26, M13, O32

1. INTRODUCTION

Over recent decades, universities have become increasingly entrepreneurial, generating value for society at large through the commercial exploitation of research outputs (Clark 1998; Guerrero and Urbano 2012) and encompassing a "third mission" alongside the traditional tasks of education and research (Etzkowitz 2003; Rothaermel et al. 2007). The transition to entrepreneurial universities has been stimulated by pressures from policy makers that view research commercialization as a key source of innovation, regional and national competitiveness and economic development (Audretsch 2007; Lam 2011; Mansfield 1998). Furthermore, reduced public research budgets have forced universities to develop alternative and complementary strategies to raise funds (Ambos et al. 2008; Shane 2004a). Finally, the passage of the US Bayh-Dole Act in 1980 (Grimaldi et al. 2011; Mowery et al. 2002; Shane 2004b), followed by similar changes in the legislative framework in most European countries (OECD 2003; Wright et al. 2008), contributed to greater diffusion and commercial exploitation of knowledge and technologies developed in academia.

Studies seeking to explain the development of entrepreneurial universities have identified a number of internal and external factors that facilitate the transformation process from traditional into entrepreneurial universities (for a comprehensive model see Guerrero and Urbano 2012; Kirby et al. 2011). The establishment of technology transfer offices (TTOs) figures prominently among university initiatives to foster the linkages between industry and science (Perkmann et al. 2013; Phan and Siegel 2006) and to formalize knowledge transfer (Siegel et al. 2007). TTOs stimulate university researchers to disclose their inventions, evaluate the commercialization potential of these inventions, and subsequently engage in various support services such as partner search, management of intellectual property rights and business development (Phan and Siegel 2006; Siegel et al. 2003). They also fulfill a dual boundary spanning role by bringing researchers into contact with experts, companies and financiers outside university boundaries, and by bridging the gaps with the central university and/or between different research teams within university boundaries (Huyghe et al. 2014).

Given the centrality of TTO establishment in the rise of entrepreneurial universities, it comes as no surprise that the academic literature has devoted considerable attention to TTOs. As we illustrate in the next section, numerous studies have investigated the way TTOs are structured (e.g., Bercovitz et al.

2001; Markman et al. 2005), the activities they perform (e.g., Huyghe et al. 2014; Siegel et al. 2007), and the entrepreneurial output they generate in terms of number of technologies licensed, patents granted and spin-offs created (e.g., Coupe 2003; Link and Scott 2005; Lockett and Wright 2005). Yet, scholars have also recognized that many researchers do not resort to TTOs when commercially exploiting their scientific discoveries but rather take inventions directly to the marketplace. For instance, in a German context, Krücken (2003) estimated a ratio of nine entrepreneurial projects set up by researchers through informal links to every formal one established through the TTO. This phenomenon has been referred to as "technologies going out the back door" (Thursby et al. 2001; Siegel et al. 2004), "the gray market of technology transfer" (Kenney and Patton 2009) or "TTO bypassing" (Kumar 2010; Markman et al. 2006; 2008), and has typically been treated as undesirable behavior. TTO bypassing indeed prevents TTOs from fulfilling their role and makes universities miss out on opportunities to generate revenues (Markman et al. 2008).

We argue that researchers may not always purposefully bypass the TTO when they decide to commercially exploit their research outputs. A researcher may take an invention directly to the marketplace simply because s/he is not aware that a TTO exists at the university. As a result, Sellenthin's (2009) conclusion that researchers who regard the support of the TTO as helpful or valuable will not circumvent it, only holds if the researchers have detected the TTO, and can thus evaluate its activities and decide whether or not to call upon its support. This may seem a trite observation but is perhaps not surprising in the complex context of a university environment. It is consistent with Schmiemann and Durvy's (2003) suggestion that TTOs need to gain much more visibility in order to act more effectively. Along the same lines, O'Kane et al. (2015) accentuated the need for TTO legitimacy-building if technology transfer officers are to act as agents of change in establishing academic entrepreneurship as a legitimate and desirable activity. Accordingly, we suggest that a necessary condition for researchers to consult the TTO and to take advantage of its services is TTO awareness.

Surprisingly, to date, no scholars have considered the extent to which researchers are aware of the existence of a TTO at their university, nor analyzed factors that explain heterogeneity in TTO awareness. To address this knowledge gap, our study investigates the impact of a series of individual attributes on TTO awareness. Specifically, using information-processing theory complemented by insights from the knowledge corridor thesis, we discuss how researchers' work experience in the private sector, engagement with industry through research and consulting contracts, scientific discipline and position at the university affect the likelihood of detecting the TTO within their university. To empirically examine these individual-level determinants of TTO awareness, we employ a unique cross-sectional dataset of 3,250 researchers in 24 universities located in five culturally different European countries.

Our study enriches prior work on TTOs by highlighting that not all TTO bypassing behavior is deliberate: a lack of TTO awareness may be a major limiting factor in researchers' ability to use TTO services. To our knowledge, this research is the first to propose and test factors associated with TTO awareness, thereby recognizing the importance of researchers' individual attributes. In so doing, our study contributes to the wider literature on entrepreneurial universities by revealing under which circumstances TTOs are less (more) likely to be detected by researchers thus making the commercial exploitation of research outputs more (less) difficult. Next to being relevant to scholars, our study has valuable implications for practitioners, including university managers and policy makers. Indeed, if researchers do not detect the TTO, this may result in TTO bypassing and a potential loss of commercialization income to the university. Furthermore, as TTOs are supposed to support researchers in their commercialization attempts, lack of TTO awareness may result in suboptimal exploitation of inventions. In particular, for university managers for whom technology transfer effectiveness is an issue of strategic importance, our findings indicate that they should implement initiatives to enhance TTO awareness among those cohorts that are unlikely to find their way to its services. Our results further suggest that policy remedies targeted at increasing the disclosure rates of inventions to TTOs could be misdirected in case these policy actions do not comprise the enhancement of the TTO's visibility among university researchers.

The remainder of this paper is organized as follows. We first present our theoretical framework and hypotheses, followed by a description of our data collection procedure and variable construction. Subsequently, we present our findings, discuss the theoretical and managerial implications of our results, and propose directions for further research.

2. THEORETICAL BACKGROUND AND HYPOTHESES

Scholars have dedicated extensive attention to TTOs. Table 1 represents the most significant contributions to the literature on TTOs since 2000. The table indicates a strong emphasis on TTO characteristics, commercialization processes and performance, while signaling scarce attention to the phenomenon of TTO bypassing and a lack of recognition of the crucial role of TTO awareness.

<< Insert Table 1 about here>>>

We explain why some researchers detect the TTO within their university while others do not, building upon insights from information-processing theory and the knowledge corridor thesis.

Information-processing theory recognizes that there are differences in the way people select, acquire and interpret information in their environment (Lord and Maher 1990). Such diversity originates from individuals' cognitive processes (Forbes 1999) or the fact that people tend to occupy different and unique "information environments" (Huber and Daft 1987), i.e. the subset of information in the environment that is subject to being sensed varies from one person to another. This psychological theory has so far been successfully integrated in management and entrepreneurship studies on new venture creation (Forbes 1999; Shaver and Scott 1991), fund raising (Vanacker and Forbes 2015) and strategic decision making (May et al. 2000; Van Knippenberg et al. 2015).

A basic tenet of the theory is that information-processing is particularly demanding in complex environments (Forbes 1999), characterized by high levels of information load and diversity (Hansen and Allen 1992). In such environments, large volumes of ambiguous information make it challenging for individuals to scan all relevant information and reduce the degree of overlap among the information sources scanned by different individuals (Forbes 1999). This is the case in the context of our study. Due to their divergent strategic goals, the variety of external and internal stakeholders they deal with, and their inherent labor intensity (Bartell 2003; O'Kane et al. 2015), universities can be considered complex environments. The abundance of information implies strong competition for individuals' attention (Simon, 1971). Hence, there is likely to be great heterogeneity in terms of the information scanned and attended to by different researchers, or the information environments that different researchers occupy. This logic implies that researchers may be more or less likely to detect the TTO based on differences in their particular information environments. In what follows, we discuss how such diversity can stem from their individual attributes, drawing on insights from information-processing theory and the knowledge corridor thesis.

The primary base underlying information-processing is knowledge. Cognition proceeds by exploiting the knowledge individuals have acquired from experience (Anderson 1990). Put differently, experience-based knowledge can induce 'cognitive pathways' influencing the amount and the nature of the information that people process (Fiet 2007). In particular, an individual's idiosyncratic life circumstances, including prior (work and educational) experiences, create a "knowledge corridor" that shapes the information s/he can see, interpret and respond to (Ronstadt 1988; Venkataraman 1997).

Several entrepreneurship scholars have built on the knowledge corridor thesis to explain how prior experiences lead to differences in the likelihood of identification and exploitation of opportunities for the commercialization of new products and services (Ardichvili et al. 2003; Gruber et al. 2013; Shane 2000) as well as opportunities for innovation (Cliff et al. 2006; Shepherd and DeTienne 2005). It is well acknowledged that individuals are more capable of navigating aspects of the venture creation process when they have relevant knowledge (Davidsson and Honig 2003; Shane 2000). In this way,

information-processing and cognition play a pivotal role in entrepreneurial alertness (Forbes 1999; Gaglio and Katz 2001; Mitchell et al. 2002). As individuals have a tendency to mostly notice information related to the information they already know (Von Hippel 1994), they are usually unaware of opportunities that lie outside their knowledge corridor. We extend the knowledge corridor thesis beyond the discovery of entrepreneurial opportunities, and argue that a researcher's pre-existing knowledge will influence her/his likelihood to identify research commercialization support in a university context.

Researchers with work experiences limited to the traditional university tasks of education and research are located in a knowledge corridor (hereafter, the academic knowledge corridor) that makes them poorly receptive to research commercialization opportunities and, thus, relatively unlikely to detect the TTO at their university. Conversely, knowledge acquired through work experiences outside academia (either prior to the academic job or concurrent with it) enables researchers to escape the academic knowledge corridor and leads them to occupy different information environments. In what follows, we assess how different experiential dimensions of researchers' knowledge base can give rise to a non-academic knowledge corridor and increase the likelihood of TTO awareness.[1]

Inter-sectoral experiences throughout their career, i.e. jobs in both industrial and academic contexts, provide researchers with broader and more diverse skills and networks (Dietz and Bozeman 2005). In particular, work experience in the private sector as either employees or entrepreneurs allows individuals to gain knowledge about industrial needs, market functioning and the differences between science and industry (Wennberg et al. 2011). Such knowledge is likely to direct individuals' attention to and interpretation of environmental stimuli, thus shaping their information environments. Furthermore, as entrepreneurs must be multi-skilled (Lazear 2004; Stuetzer et al. 2013), they tend to invest in acquiring the broad knowledge base required to run a business. As such, employee or entrepreneurial experience provides researchers with specific human and social capital (Mosey and Wright 2007; Westhead et al. 2009), and leads researchers to occupy broader information environments than the traditional academic one. Therefore, work experience in the private sector makes researchers alert not only to commercialization opportunities but also to commercialization initiatives in place at the university, such as the TTO's existence. Hence:

> **Hypothesis 1a**: Researchers with industry work experience as employees are more likely to be aware of the TTO's existence than researchers who lack such experience.
> **Hypothesis 1b**: Researchers with industry work experience as entrepreneurs are more likely to be aware of the TTO's existence than researchers who lack such experience.

Experience in industry-science interaction, gained through prior engagement in contract research and consulting activities with the private sector, could also lead researchers to occupy broader information environments and enable them to escape the academic knowledge corridor. Researchers who closed more research and consulting contracts with industry are likely to possess a stronger orientation towards the application of scientific knowledge rather than basic research (Perkmann and Walsh 2008), and to have a better understanding of business needs and the market potential of their scientific discoveries (Gulbrandsen and Smeby 2005; Krabel and Mueller 2009; Murray 2004). Additionally, engagement with industry allows researchers to build ties outside their academic network with potential customers or partners (Perkmann et al. 2013), and increases their awareness of the latent benefits and problems related to the commercialization of research results (Fritsch and Krabel 2012). Accordingly, the knowledge acquired through interactions with industry will broaden individuals' information environments. These researchers are thus likely to have a superior ability to recognize research commercialization opportunities and, by extension, a greater likelihood to possess information about the existence of a TTO at their university. Therefore, we predict a positive

[1] It is worth acknowledging that, while we identified the individual attributes building upon information-processing arguments, prior research on academic entrepreneurship has also generally accepted these attributes as important human and social capital dimensions (e.g., Ambos et al. 2008; Mosey and Wright 2007; Powers and McDougall 2005; Toole and Czarnitzki 2010).

association between the number of research and consulting contracts that a researcher has closed with industry and her/his TTO awareness. Hence:

> **Hypothesis 2**: Researchers who closed more research and consulting contracts with industry are more likely to be aware of the TTO's existence.

Individual differences in the information environments can also stem from researchers' scientific discipline, making it more (or less) likely for the researchers to detect the TTO. Specifically, medical inventions generally have greater marketability than inventions from other disciplines (Powers 2003), and researchers at medical faculties typically work at the intersection of basic and applied research (Stuart and Ding 2006). Similarly, commercialization has become an institutionalized practice in engineering and life sciences (Bercovitz and Feldman 2008; Kenney and Goe 2004; Lee 1996). Conversely, research results in other disciplines (for instance, in social and behavioral sciences) are typically less application-oriented (Pilegaard et al. 2010), making it less likely that such researchers scan and attend to information that is not purely academic. Accordingly, we contend that the scientific discipline is a key determinant of researchers' information environments, providing them with the ability to assimilate market-related knowledge and making them more (or less) likely to move beyond the academic knowledge corridor, and to be more (or less) aware of technology transfer practices and the existence of a TTO as facilitator in the process. Hence:

> **Hypothesis 3**: Researchers active in medicine, engineering or life sciences are more likely to be aware of the TTO's existence than researchers in other disciplines.

Researchers' differences in the information environments occupied also depend on the time spent in academia. Pre-doctoral researchers are more likely to occupy narrow information environments and to be stuck in an academic knowledge corridor. Being newcomers in academia, they need to create the external perception that they are legitimately operating in the scientific community. As engagement in publication efforts is essential for the establishment of academic reputation (Gittelman and Kogut 2003; Link et al. 2007), pre-doctoral researchers will exhibit strong commitment in terms of time and orientation to furthering their publication activities and building related skills, and be less concerned about the commercial exploitation of their research results. Similarly, network-building activities of pre-doctoral researchers are likely to be primarily focused on building social capital within the scientific community they are entering. Taken together, the specific nature of pre-doctoral researchers' human and social capital likely makes them trapped in the academic knowledge corridor and prevents them from observing commercialization initiatives such as the existence of a TTO at their universities. Researchers are however more likely to escape the academic knowledge corridor as they gain work experience in academia (Knockaert et al. 2015). Indeed, as time passes, the chance of researchers to get in touch with other knowledge corridors, just as the chance of becoming aware of TTO's existence, increases. Therefore, we expect the likelihood of detecting the TTO to be greater for post-doctoral than for pre-doctoral researchers. Hence:

> **Hypothesis 4:** Post-doctoral researchers are more likely to be aware of the TTO's existence than pre-doctoral researchers.

3. METHODOLOGY

3.1. Data Collection and Sample

Our study utilizes a unique cross-sectional dataset constructed in 2012 and 2013 through face-to-face interviews with TTO managers and an online survey directed to university researchers. The data were collected at 24 universities in five European countries. The five countries were selected building upon the societal clusters proposed by the Global Leadership and Organizational Behavior Effectiveness research program (GLOBE), that groups countries on the basis of cultural dimensions (Gupta et al. 2002; Javidan et al. 2006). Starting from the GLOBE clusters in Europe, we randomly selected one country per cluster: Sweden (Nordic Europe), Spain (Latin Europe), Slovenia (Eastern

Europe), Germany and Belgium (German-speaking and Dutch-speaking Germanic Europe). Then, we randomly selected two level 1 NUTS regions within each country with the exception of Slovenia, where only one level 1 NUTS region exists (i.e., SI0). The regions selected were the following ones: East Sweden (SE1) and South Sweden (SE2), Community of Madrid (ES3) and East Spain (ES5), Bavaria (DE2) and North Rhine-Westphalia (DEA), Brussels Capital (BE1) and Flanders (BE2). Next, we made a list of all the universities located in those geographical regions using secondary sources (including reports by ministries of education, university rankings, technology transfer networks and general internet searches), and contacted their TTOs through email and/or telephone. TTO managers in 40 out of the 58 universities identified and contacted were willing to take part in our research. Nine of the 40 universities were dropped due to respondents' ultimate unavailability to participate in face-to-face interviews. Another seven universities were excluded as the distribution of our survey among researchers was unfeasible due to privacy policies or nonexistence of staff directories. We thus have a final sample of 24 universities.

During the interviews with the TTO managers of these 24 universities[2], we acquired information on a range of university and TTO characteristics (e.g., human and financial resources, annual commercialization output, history and structure of the TTO). Primary data were verified and complemented with secondary data from annual reports, and university and TTO websites. Moreover, we asked for assistance to contact pre- and post-doctoral researchers from different scientific disciplines within each university and requested them to fill out our online questionnaire. Our survey deliberately targeted non-tenured academic staff, as they constitute an important but often overlooked channel for knowledge transfer that will shape entrepreneurial universities in the future (Bienkowska and Klofsten 2012; Thune 2009).

The survey population consisted of 32,358 pre- and post-doctoral researchers. We received 6,442 failure messages indicating that email addresses were invalid or our message could not be sent, resulting in a usable population of 25,916 researchers. A total of 4,515 responses were received (17% of the usable population. Exclusion of partial responses resulted in a final sample of 3,250 researchers who fully completed the required questions (12.5% of the usable population). T-tests revealed no statistically significant differences between respondents who filled in all questions and those who provided incomplete responses, and between early and late respondents, in terms of age, gender, educational background, discipline or country.

3.2. Measures

3.2.1. Dependent Variable

TTO awareness was measured through the online questionnaire by asking researchers whether they were aware of the existence of a TTO at their university. The variable takes a value of 1 where the researcher has detected the TTO and 0 otherwise.

3.2.2. Explanatory Variables

Employee experience and *Entrepreneurial experience* are two binary variables captured by asking researchers whether they had previously been employed in the private sector, and whether they had ever started their own business, respectively. Both variables were coded 1 if the answer was positive and 0 otherwise. 32% of the respondents reported to possess industry work experience as an employee, 16% stated they had entrepreneurial experience.

Number of contracts was assessed through the online survey by asking researchers to specify how many research and consulting contracts they had closed with partners in the private sector. The

[2] Information on the universities included, length and structure of the interviews, and data collected during the interviews can be obtained from the authors upon request.

average number of contracts closed per researcher was 0.61. The distribution of this variable is skewed as only 13% of our respondents indicated that they had engaged in industry-science interaction, and the average number of contracts these researchers had closed was 4.5. Accordingly, we computed the variable as the natural logarithm of the number of closed contracts.

Scientific discipline dummies were included in our analyses, using the responses to the online questionnaire. 15% of the researchers in our sample were active in medicine & pharmaceutical sciences, 25% in engineering, technology & computer sciences, 14% in life & agricultural sciences, and the remaining 46% conducted research in other disciplines (i.e. in 16% natural sciences & mathematics, and 30% in social & behavioral sciences). Throughout our analyses, the "other" category is used as the reference category.

Post-PhD is a dummy variable denoting whether the survey respondent was a pre-doctoral (value 0) or post-doctoral researcher (value 1). 35% of the researchers in our sample were occupying a post-doctoral position.

3.2.3. Control Variables

Gender is a dummy variable that indicates whether the researcher is male (value 0) or female (value 1). Following prior research on technology transfer, men are generally more likely to engage in commercialization endeavors than women (e.g., Landry et al. 2007). This difference may similarly be associated with a diverse likelihood of detecting the TTO at the researcher's university. The data obtained through the online questionnaire indicates that 51% of our sample consists of men.

Technical degree and *non-technical degree* are two binary variables (0 = no, 1 = yes), capturing whether the researcher had a technical degree (e.g., bio-science, physics, electronics, mechanics, robotics, telecom, etc.) and/or a non-technical degree (e.g., economics, law school, psychology, etc.). We included these controls as prior work has shown that individuals with a technical background are more likely to engage in entrepreneurial activities (Mosey and Wright 2007). The results of the online questionnaire show that 45% of the respondents had a technical degree, 36% had a non-technical degree, 4% had both, and the remaining 15% did not have a degree.

Scientific productivity is measured as a researcher's number of publications, as s/he self-reported in the online questionnaire. Specifically, in line with prior research (e.g. Erikson et al. 2015), we asked researchers to report on their total publications in scientific journals or books incorporated in the (social) science citation index list. The respondents in our sample had an average of 9 publications, with 27% having no publication output (yet). Because of the skewed distribution, we computed the variable as the natural logarithm of the number of publications.

TTO size is computed as the total number of FTE staff working for the TTO (including IP and licensing staff, excluding staff employed in science parks or incubator facilities). This control was included as larger organizational units are likely to gain more visibility than smaller ones (Pfeffer 1972). Information to build the variable was obtained directly from the TTO managers during face-to-face interviews, and verified with secondary data (i.e., TTO websites and reports). On average, the number of FTE staff in the TTOs of sample universities was 24. Following the distribution of the number of FTE staff, the variable TTO size was computed as the natural logarithm of this number.

Traditional TTO structure was assessed during the interviews with the TTO managers, drawing on Markman et al.'s (2005; 2008) classification of TTOs based on the degree of structural autonomy they have in the pursuit of research commercialization. Traditionally structured TTOs reside inside universities, are run and controlled by university management, and generally consist of university staff. In contrast, non-traditional TTO structures are established outside universities, have largely independent management and function mostly autonomously. Taking into account TTOs' structural autonomy is warranted given its implications for the coordination of activities, the facilitation of internal and external information flows and the alignment of incentives (Bercovitz et al. 2001). As

such, structural autonomy is likely to affect whether the TTO's existence belongs to researchers' information environments. This variable takes a value of 1 in the case of a traditional TTO structure and 0 otherwise. 34% of the respondents were found to reside in a university incorporating a traditional TTO structure.

Professor's privilege was included as a control variable in our analyses, because differences in institutional regimes are likely to affect technology transfer practices (Damsgaard and Thursby 2013; Klofsten and Jones-Evans 2000;). Indeed, while in some regimes, full ownership of intellectual property rights is asserted to university researchers, other regimes divide ownership between the university (and its subunits) and the researchers or fully grant ownership to the university. In our sample, researchers were employed at universities in Sweden (25%), Germany (25%), Spain (16%), Slovenia (5%) and Belgium (29%). While Sweden gives full ownership of intellectual property rights to researchers, also labelled the professor's privilege or academic exemption, this is not the case in the other countries. Therefore, we included a dummy variable capturing whether the researcher is employed at a Swedish university, i.e. in a country the professor's privilege applies (value 1), or not (value 0).

3.3 Analytical approach

We used hierarchical logistic regression analysis to test our hypotheses. The models are adjusted for 24 university clusters using the cluster option in STATA. This hierarchical estimation technique adjusts the standard errors by computing a cluster robust standard error for the coefficient, as such accounting for potential unobserved university effects.

4. RESULTS

4.1. General Findings

Table 2 provides an overview of the descriptive statistics and correlations. Interestingly enough, our data confirm the relevance of our research: TTO awareness cannot be taken for granted as less than half of our sample, or 44% of the respondents, detected the TTO at their university. Table 2 also reveals that correlations among explanatory variables tend to be low. In addition, the variance inflation factors are all below 5 (maximum VIF = 3.14), indicating that multicollinearity is unlikely to be a concern in our study (Hair et al. 2010).

<< Insert Table 2 about here>>>

Table 3 subsequently presents the results of our analyses on the researcher attributes associated with TTO awareness.

<< Insert Table 3 about here>>>

The coefficients of the control variables in the full model indicate that female researchers are less likely to be aware of the TTO. Furthermore, we find that a higher level of publication output positively affects the likelihood of TTO awareness. Finally, our results show that researchers working in universities incorporating a TTO with a traditional structure, and those employed at Swedish universities which have the professor's privilege, are less likely to be aware of the TTO's existence.

Regarding the results with respect to our explanatory variables we find the following. First, as to the effect of industry work experience, we **do not find support for Hypothesis 1a**, which suggested a positive relationship between experience as an employee in the private sector and TTO awareness. However, our analyses provide **support for Hypothesis 1b**, which proposed a positive link between entrepreneurial experience and TTO awareness ($B=.49$, $p<.01$). When a researcher has had experience as an entrepreneur, the odds of TTO awareness go up by 62%. We also find a positive influence of the number of research and consulting contracts closed by the researcher. The results show that for every

increase in the natural logarithm of the number of contracts closed (or for every increase by 2.7 contracts), there is an increase in the odds of being aware of the TTO's existence by 3% ($p<.01$). As such, our empirical evidence **corroborates Hypothesis 2**. As for scientific discipline, we find that researchers active in medicine & pharmaceutical sciences ($B=.52$, $p<.001$), engineering, technology & computer sciences ($B=.44$, $p<.01$), and especially in life & agricultural sciences ($B=.88$, $p<.001$) are more likely to have identified the university TTO than their peers conducting research in the other disciplines. As such, we also find **support for Hypothesis 3**. Finally, our results indicate that post-doctoral researchers are more likely to be aware of the TTO's existence compared to pre-doctoral researchers, which **provides support for Hypothesis 4**. Specifically, the odds of a post-doctoral researcher detecting the TTO are 107% above those of a pre-doctoral researcher.

4.2. Robustness Checks

We conducted a number of additional analyses to assess the robustness of our results.

First, although we corrected for potential unobserved university effects, other cluster effects may have biased our results. Researchers in our sample are also embedded in different departments, and recent research has pointed to the importance of departmental influences (Bercovitz and Feldman 2008; Rasmussen et al. 2014). While most statistical packages only allow clustering by one variable, we followed Petersen (2009) and used the logit2 command in STATA to apply two-dimensional clustering, in which the models were adjusted for potential unobserved effects due to both department- and university-grouping. The results remained identical after controlling for both department-specific (501 departments) and university-specific (24 universities) error components.

Second, we carried out robustness checks to address potential endogeneity issues. In particular, researchers who had detected the TTO may already have contacted it and closed research and consulting contracts with industry thanks to the TTO's support. In this case, industry-science interaction experience does not help researchers to escape the traditional academic corridor thus making them more likely to detect the TTO, but it is the TTO that enables researchers' engagement in contracts with industry. In order to rule out this alternative explanation, as we had also asked survey respondents whether they had ever been in contact with the TTO, we reran our analyses with this alternative dummy as dependent variable. If the positive association between the number of closed contracts and TTO awareness were in fact the result of the positive impact of TTO contact on the number of research or consultancy contracts, our additional analyses would reveal a positive association between industry-science interaction experience and our new dependent variable. However, the estimates of this latter model do not provide indications of any statistically significant relationship between the number of contracts closed by researchers and the likelihood that they contacted the TTO. Accordingly, we are confident that our findings are not caused by these alternative explanations.

5. DISCUSSION

While the literature on entrepreneurial universities has devoted substantial attention to the TTO as a key intermediary in the process of research commercialization, much less is known about the occurrence of TTO bypassing behavior among researchers. This study contends that circumvention of the TTO may stem from the fact that researchers are unaware of the existence of a TTO at their university. The empirical evidence in a sample of 3,250 researchers in 24 European universities supported this argument: less than half of our respondents (i.e. 44% of our sample) had identified the TTO at their university. Hence, while we recognize that investigating the determinants of TTO bypassing behavior is important, it is at least as relevant to shed light on the antecedents of TTO awareness. To the best of our knowledge, no prior work has studied such factors.

Building upon information-processing theory, we argued that differences in TTO awareness may result from differences in researchers' information environments. Drawing on the knowledge corridor thesis, we formulated and tested hypotheses on the relationships between a series of individual

attributes and TTO awareness. Our main results indicate that the researchers who possess entrepreneurial experience, those who are in a post-doctoral position, as well as those who closed more research and consulting contracts with industry, are more likely to detect the TTO. Surprisingly, we did not observe a positive link between work experience as an employee in the private sector and TTO awareness. Furthermore, we found that researchers in medicine, engineering or life sciences have a higher likelihood of detecting the TTO than their peers in other scientific disciplines. Interestingly enough, our controls also reveal that highly productive researchers in terms of publication output are more likely to be aware of the TTO's existence. While the literature has debated whether scientific and commercial activities are to be united at the level of the individual (Larsen et al. 2011), our results point to the fact that scientific productivity is a precondition for research commercialization as it helps to identify commercialization initiatives.

5.1. Contributions to the Literature

This work primarily contributes to the literature on entrepreneurial universities, the role of knowledge in academic entrepreneurship, TTOs and information-processing.

First and foremost, our study enriches the stream of studies on entrepreneurial universities in general and TTOs specifically. This literature has extensively studied TTOs' structures, activities and outcomes, but has neglected to study TTO awareness and factors affecting such awareness. In particular, our work adds to recent studies which have drawn attention to TTO bypassing behaviors, by highlighting that TTO bypassing is not always intentional; in many cases, researchers might simply be unaware of the TTO's existence. This implies that, in order to understand under which circumstances researchers are more (or less) likely to involve the TTO in their entrepreneurial endeavors, it is crucial to take into account to which extent TTOs are detectable by researchers. Therefore, future research looking into TTO bypassing behavior will benefit from considering TTO awareness and its drivers, in that way limiting selection bias, for instance by applying a Heckman correction or two-stage method in which the first stage assesses whether researchers were aware of the TTO's existence and the second stage assesses the TTO's impact on the research commercialization process.

Second, our study complements prior work on the impact of researchers' prior knowledge on academic entrepreneurship (e.g., Mosey and Wright 2007), by suggesting that experience does not only affect the likelihood and outcomes of researchers' engagement in research commercialization, but also the likelihood of researchers calling upon the TTO when pursuing entrepreneurial endeavors, as it affects researchers' TTO awareness. In doing so, we advance our current understanding of the micro-foundations of academic entrepreneurship, calling for the revitalization of interest in the individual researcher as a key player in entrepreneurial universities. While this should not be misinterpreted as a call to move attention away from structural dimensions (such as TTOs, science parks, incubators…) of the entrepreneurial university, it is clear that such structural elements can only be effective if they are sensed by individuals and belong to researchers' information environments. As such, our work encourages future studies on the entrepreneurial university to integrate structural and individual dimensions.

In addition, this paper adds to the literature on information-processing and the knowledge corridor thesis by extending the use of these theoretical perspectives to new domains. Indeed, as Zahra and Newey (2009) argue, theory development can meaningfully occur by applying theories to new phenomena or in new settings, which allows exploring the boundaries of these theories and their robustness. On the one hand, our study responds to a call by Forbes (2007) to apply insights from information-processing theory outside managerial decision-making contexts. On the other hand, we extend the knowledge corridor thesis beyond the identification and exploitation of entrepreneurial opportunities and demonstrate its applicability in the context of the entrepreneurial university.

5.2. Implications for University Stakeholders

Our study has a number of practical implications for university stakeholders.

First, our findings suggest that TTOs should not take their visibility for granted, particularly for more junior academics. Increased efforts may be required on the part of the TTO to elicit invention disclosures and to overcome bypassing behaviors. TTOs may especially benefit from extending their reach-out efforts towards those researchers who have not gained entrepreneurial experience and who have never been engaged in contract research and consulting activities with industrial companies. Furthermore, it may be desirable to expand the promotion of TTO services towards pre-doctoral researchers, or to those researchers in disciplines such as social and behavioral sciences who are less likely to move outside of the academic knowledge corridor.

Second, university departments have an important role to play in raising awareness among their members of the existence and role of TTOs. While engagement in entrepreneurial activities has generally been assumed to be more common with researchers in engineering and life sciences (e.g., Bercovitz and Feldman 2008) or researchers who generate significant scientific output (e.g., Zucker et al. 2002), this may also be the result of higher awareness of commercialization support in general, and TTO services in particular amongst those departments. Even among engineering and science departments there may be some with less interest in commercialization, while among arts and social science departments there may be significant opportunities for commercialization. University departments in these areas might make stronger cases for TTOs to have skills related to their specific disciplines and to become more proactively involved in working with them to commercialize opportunities.

Third, university managers could help TTOs overcome their restricted visibility, for instance by fostering their promotion campaign (e.g., endorsement of TTO services in a university-wide newsletter, organization of pitch competitions involving the TTO). Alternatively, they could encourage department heads to raise awareness among their colleagues and could provide support for performance evaluations that incorporate entrepreneurial activities.

5.3 Implications for Policy

Our research may further inspire public policy makers that provide funding for establishing technology transfer functions at universities, thereby often emphasizing and measuring output in terms of spin-off creation and licensing income. By doing so, they neglect the stage before the exploitation of research with commercialization potential, during which information on technology transfer initiatives may (not) be available in the researchers' information environments. Public policy makers may seek to stimulate and incentivize universities to promote the diffusion of TTO awareness and accessibility across their faculty. A greater focus on the performance measurement of university-level commercialization efforts may mean that universities and TTOs need to become more proactive in seeking out and adding value to opportunities emanating from departments. Similarly, national level exercises aimed at assessing the impact of the research of university departments (e.g. the UK's Research Excellence Framework) might consider incorporating measures of the value of commercialization in the assessment criteria, which may in turn encourage departments to seek out TTO support.

6. CONCLUSIONS

Our study contributes to widening the research and policy debate about the development and effectiveness of entrepreneurial universities. Our study has a number of limitations that open up avenues for future research.

Our cross-sectional design allows us to study an important intermediate factor, namely TTO awareness, but prevents us from examining to what extent and under what conditions TTO awareness eventually results in increased interaction between researchers and TTOs and in more effective technology transfer. Future studies adopting a longitudinal research design could investigate these unanswered questions.

While we deliberately opted to focus on TTOs, initiatives aimed at supporting the commercial exploitation of research results at entrepreneurial universities are typically broader than TTO's existence, and also comprise science parks, university venture funds and newer developments involving (pre-)incubators or accelerators (Guerrero and Urbano 2012; Pauwels et al. 2015; Rothaermel et al. 2007). Future academic studies could purposefully extend the scope of this paper by investigating the visibility and effectiveness of such alternative commercialization support initiatives. For example, future research might explore the links between TTOs and accelerator programs, whether academics bypass TTOs and go directly to accelerator programs and what the implications are for the performance of the ventures involved. Further, as some universities are developing initiatives to attract potential academic entrepreneurs at an earlier stage, such as through pre-accelerator programs like the Imperial College CreateLab, additional studies might explore their effectiveness in either raising awareness of TTOs or providing a complement or substitute.

We have focused on individuals and their experience but future studies could additionally assess to what extent factors at different levels, namely the level of the university, faculty, department or research group, and the interaction between these levels, affect TTO awareness. For instance, future studies could look into the effects of the incentive systems in place within the university, or the collective engagement of researchers in commercialization activities at the department or research group level. We have some limited qualitative evidence regarding the nature of the relationships between TTOs and scientific departments (Mosey and Wright 2007; Wright et al. 2009), but further in-depth studies are needed, not least to explore the processes through which commercialization activities within departments do or do not develop to involve TTOs.

We also recognized some aspects of the nature of TTOs, notably their size and structure. Further studies might seek to explore in more fine-grained detail the heterogeneity of the expertise within TTOs. On one hand, such research might consider whether academics are likely to be more aware of TTOs with entrepreneurial rather than, say, only legal expertise, as they perceive them as more relevant to their commercialization attempts. In addition, future studies might explore in more detail the move by individuals from awareness to use of TTOs. Why might entrepreneurs who are aware of TTOs not use them even though prima facie they may be relevant to their commercialization efforts?

In sum, our findings suggest that researchers, universities and policy makers seeking to understand how the returns from academic entrepreneurship can be enhanced need to explore both the structural characteristics of TTOs as well as the behavior of researchers. Importantly, it suggests that not all commercialization activities by researchers in which they do not consult the TTO should be considered undesirable behavior as TTOs often lack visibility within their universities. This problem is particularly severe with certain types of researchers.

Table 1: Studies on Technology Transfer Offices from 2000

Author(s)	Data	Key Results
Foltz, Barham and Kim (2000)	AUTM, NSF	Faculty quality, federal research funding, and number of TTO staff have a positive impact on university patenting
Rogers, Yin and Hoffmann (2000)	AUTM, NSF, NRC	Positive correlation between faculty quality, age of TTO, and number of TTO staff and higher levels of performance in technology transfer
Bercovitz, Feldman, Feller, and Burton (2001)	AUTM and Case Studies, Interviews	Analysis of different organization structures for technology transfer at Duke, Johns Hopkins, and Penn State; differences in structure may be related to technology transfer performance
Franklin, Wright, and Lockett (2001)	Authors' Quantitative Survey of U.K. TTOs	Universities that wish to launch successful technology transfer startups should employ a combination of academic and surrogate entrepreneurship
Thursby, Jensen, and Thursby (2001)	AUTM, Authors' Survey	Inventions tend to disclosed at an early stage of development; elasticities of licenses and royalties with respect to invention disclosures are both less than one; faculty members are increasingly likely to disclose inventions.
Carlsson and Fridh (2002)	AUTM	Research expenditure, invention disclosures, and TTO age have a positive impact on university patenting and licensing
Thursby and Kemp (2002)	AUTM	Faculty quality and number of TTO staff has a positive impact on various technology transfer outputs; private universities appear to be more efficient than public universities; universities with medical schools less efficient
Thursby and Thursby (2002)	AUTM and Authors' Own Survey	Growth in university licensing and patenting can be attributed to an increase in the willingness of professors to patent and license, as well as outsourcing of R&D by firms; not to a shift towards more applied research
Friedman and Silberman (2003)	AUTM, NSF, NRC, Milken Institute "Tech-Pole" Data	Higher royalty shares for faculty members are associated with greater licensing income
Lockett, Wright, and Franklin, (2003)	Quantitative and Qualitative Surveys of U.K. TTOs	Universities that generate the most startups have clear, well-defined spinoff strategies, strong expertise in entrepreneurship, and vast social networks
Siegel, Waldman, and Link (2003)	AUTM, NSF, and U.S. Census Data, Interviews	TTOs exhibit constant returns to scale with respect to the # of licensing; increasing returns to scale with respect to licensing revenue; organizational and environmental factors have considerable explanatory power
Lach and Schankerman (2004)	AUTM, NSF, NRC,	Higher royalty shares for faculty members are associated with greater licensing income
Markman, Phan, Balkin, and Gianiodis (2004)	AUTM Survey, Authors' Survey	There are three key determinants of time-to-market (speed): TTO resources, competency in identifying licensees, and participation of faculty-inventors in the licensing process
Chapple, Lockett, Siegel, and Wright (2005)	U.K.-NUBS/ UNICO Survey-ONS	U.K. TTOs exhibit decreasing returns to scale and low levels of absolute efficiency; organizational and environmental factors have considerable explanatory power
Clarysse, Wright, Lockett, van de Velde and Vohora (2005)	Interviews and descriptive data on TTOs in 50 universities across 7 European countries	Five incubation models identified. Three match resources, activities & objectives: low selective, supportive & incubator. Two do not: competence and resource deficiency.
Link and Siegel (2005)	AUTM, NSF, and U.S. Census Data, Interviews	Land grant universities are more efficient in technology transfer; Higher royalty shares for faculty members are associated with greater licensing income
Lockett and Wright (2005)	Survey of TTOs in the UK	A university's rate of start-up formation is positively associated with its expenditure on intellectual property protection, the business development capabilities of TTOs, and the extent to which its royalty distribution formula favors faculty members
Markman, Phan, Balkin, and Gianiodis (2005)	AUTM Survey, Authors' Survey	The most attractive combinations of technology stage and licensing strategy for new venture creation-early stage technology and licensing for equity-are least likely to favored by the university (due to risk aversion and focus on short-run revenue maximization)
Mosey and Wright (2007)	Longitudinal qualitative interviews with academic entrepreneurs and TTOs in the UK	Nascent academic entrepreneurs frustrated by lack of assistance from TTOs and advice from TTOs less valuable than from other sources. Novice entrepreneurs gave TTO assistance more credence than did nascents. Habitual academic entrepreneurs had mixed views on TTOs but TTO often seen as a barrier regardless of TTO capabilities.
Belenzon and Schankerman (2009)	Survey of TLOs in USA, AUTM, USPTO	The adoption of incentive pay in TLOs increases the level of income per license while strong local development objectives and government constraints reduce it.

Sellenthin (2009)	Survey of professors in Sweden and Germany	Researchers that received support from the TTO and those that have experience with the patenting system are much more likely to apply for patents
Caldera and Debande (2010)	RedOTRI survey on university technology transfer in Spain	TTO size, experience and specialization have a positive effect on R&D contract activity. TTO size positively affects also the number of licenses and spin-offs created.
Muscio (2010)	Survey of 197 department heads in Italy	University research performance, business-oriented management of TTOs and greater receptiveness of university departments to TTO services, positively affect the probability of the TTO being involved in university–industry collaboration.
Algieri, Aquino and Succurro (2013)	Survey of TTOs in Italy	Key factors for increasing spin-offs are sizeable financial resources and full-time highly-skilled employees. The age of the TTO does not influence the capacity to create additional spin-offs. Regional factors are influential in the number of spin-offs.
Hulsbeck, Lehmann and Starnecker (2013)	Survey of TTOs in German universities	The division of labor and specialization of tasks in the TTO have a positive effect on the number of invention disclosures.
Huyghe, Knockaert, Wright, and Piva (2014)	Qualitative interviews of hybrid TTO in Belgium	Centralized and decentralized TTOs perform differently in the types of boundary spanning activities and in the parties they engage with. Geographical, technological and organizational proximity are important antecedents of the TTOs' engagement in external and internal boundary spanning activities.
Schoen, van Pottelsberghe de la Potterie, and Henkel (2014)	16 case studies of TTOs in 6 European countries	Four main types of TTOs are identified: (1) classical TTO; (2) autonomous TTO; (3) discipline-integrated Technology Transfer Alliance; and (4) discipline-specialized Technology Transfer Alliance, and analysis provided of how universities organize their technology transfer and intellectual property management.
Brescia, Colombo, and Landoni (2015)	Analysis of the top 200 universities worldwide	Identifies the presence of three knowledge transfer organizational models (internal, external, and mix) and six configurations of these models
Derrick (2015)	Interviews with TTO personnel and researchers in 5 Australian medical research organizations	The flexibility of TTO personnel to researcher needs, the offer of collective incentives, and the visibility within the organization contribute to the success of TTOs integrated in the organizational structure
O'Kane, Mangematin, Geoghegan, and Fitzgerald (2015)	Interviews with TTO executives across 22 universities in Ireland, New Zealand and the United States	TTOs use identity-conformance and identity-manipulation to shape a dual identity, one scientific and the other business, with academics and management respectively. This combination of identity strategies is ineffective for legitimizing the TTO as TTOs' identity shaping strategies are incomplete and need to incorporate a distinctive identity to complement and reinforce preliminary legitimacy claims made through conformance and manipulation.
Shane, Dolmans, Jankowski, Reymen and Romme (2015)	Randomized experiment with 200 TLOs in the US	TLOs make use of the representativeness heuristic of a typical inventor-entrepreneur when deciding which inventors' technologies should/should not be commercialized through the founding of new companies
Weckowska (2015)	Qualitative interviews of 6 TTOs the UK	TTOs adopt two approaches to learning in the research commercialization process, namely transactions-focused practice and relations-focused practice.

Source: Adapted and updated based on Siegel and Wright (2015)

Table 2: Correlations and Descriptive Statistics

Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	TTO awareness	1														
2	Employee experience	**-.05**	1													
3	Entrepreneurial experience	**.07**	**-.30**	1												
4	Number of contracts	**.14**	**.04**	**.12**	1											
5	Medicine & pharmaceutical sciences	.01	**-.06**	**.03**	**-.07**	1										
6	Engineering, technology & computer sciences	**.08**	**.08**	**.06**	**.21**	**-.25**	1									
7	Life & agricultural sciences	**.10**	**-.03**	**-.08**	-.02	**-.17**	**-.23**	1								
8	Post-PhD	**.19**	**-.04**	.03	**.09**	.02	**-.12**	**.05**	1							
9	Gender	**-.12**	-.03	**-.11**	**-.10**	**.17**	**-.26**	**.06**	-.01	1						
10	Technical degree	**.12**	.03	-.03	**.14**	**-.13**	**.43**	**.13**	**-.03**	**-.22**	1					
11	Non-technical degree	**-.13**	.02	**.06**	**-.07**	.00	**-.36**	**-.15**	-.00	**.18**	**-.65**	1				
12	Scientific productivity	**.13**	-.03	**.05**	**.03**	**.07**	**-.05**	-.00	**.38**	**-.03**	.01	-.03	1			
13	TTO size	**.09**	**-.09**	**-.10**	**-.08**	**.11**	**-10**	**.08**	**-.11**	**.04**	-.04	.03	**-.06**	1		
14	Traditional TTO structure	**-.07**	**08**	.01	**.06**	**-.21**	**.17**	**-.12**	**-.07**	**-.09**	**.05**	-.03	**-.05**	**-.48**	1	
15	Professor's privilege	**-.16**	**.05**	**.10**	**-.05**	**.17**	-.04	**.09**	.02	.00	**.05**	-.03	.03	**-.16**	**-.35**	1
Mean		.44	.32	.16	-15.84	.15	.25	.14	.35	.49	.49	.40	-5.54	2.73	.34	.25
SD		.50	.46	.37	6.57	.36	.44	.35	.48	.50	.50	.49	13.83	1.02	.47	.43

Pearson correlation coefficients (1-tailed), indicating significant correlations (p<.05) in **bold** (n = 3,250)
Correlations of binary variables (1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 14, 15) should be interpreted with care

Table 3: Hierarchical Logistic Regression Analysis for TTO awareness (adjusted for university clusters)

	Control model		**Full model**	
	B (s.e)	e^B (odds ratio)	B (s.e.)	e^B (odds ratio)
Explanatory variables				
Employee experience (H1a)			.00(.11)	1.00
Entrepreneurial experience (H1b)			.49**(.16)	1.62
Number of contracts (H2)			.03***(.01)	1.03
Scientific discipline (H3)				
Medicine & pharmaceutical sciences			.52***(.16)	1.68
Engineering, technology & computer sciences			.44**(16)	1.55
Life & agricultural sciences			.88***(.13)	2.41
Post-PhD (H4)			.73***(.10)	2.07
Control variables				
Gender	-.45***(.11)	.64	-.44***(.10)	.64
Technical degree	.30***(.09)	1.35	.20(.10)	1.22
Non-technical degree	-.36*(.17)	.70	-.24(.13)	.79
Scientific productivity	.02***(.00)	1.02	.01***(.00)	1.01
TTO size	-.04(.08)	.96	.02(.07)	1.02
Traditional TTO structure	-.79***(.17)	.45	-.69***(.19)	.50
Professor's privilege	-1.22***(.22)	.30	-1.35***(.22)	.26
Constant	.73*(.29)	2.07	.36 (.34)	1.43
Model specification				
χ^2	124.91***		307.46***	
Log Likelihood	-2063.70		-1967.06	
Pseudo R^2	.07		.12	

Unstandardized regression coefficients with standard errors are reported in the table.
*p<.05; **p<.01; ***p<.001 (n = 3,250)

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