Technology Transfer Office as Providers of Science and Technology Entrepreneurship Education

TECHNOLOGY TRANSFER OFFICES AS PROVIDERS OF SCIENCE AND TECHNOLOGY ENTREPRENEURSHIP EDUCATION

ABSTRACT

Universities show an increasing commitment to stimulate science- and technology-based entrepreneurship with the aim of contributing to societal and economic development. The provision of science and technology entrepreneurship education (STEE) and the operation of technology transfer offices (TTOs) share the objective of improving university capabilities and output in science-based entrepreneurship. The literature has addressed STEE initiatives and TTOs separately. This paper reports the first comprehensive study of TTO involvement in STEE. From a sample of 176 university TTOs across 28 European countries, we found that 71 percent of TTOs were involved in the provision of STEE. The extensive involvement in STEE indicates that TTOs play an active role in stimulating universities' entrepreneurial capabilities beyond specific licensing and spin-off cases. We analyze how the characteristics of TTOs and universities potentially influence the scope of STEE involvement in terms of breadth of contents, target audiences and duration. We find that older, strategically autonomous TTOs that are located in universities attributing strong relevance to technology transfer activities are particularly active in STEE. The active role of TTOs in STEE has implications for understanding the entrepreneurship education ecosystem of universities and offers interesting opportunities for further research.

Keywords: entrepreneurship education; research commercialization; technology transfer; technology transfer office

JEL Codes: L26; I21; I23; O33

1. INTRODUCTION

Universities worldwide are seen as key institutions for facilitating job and wealth creation in an entrepreneurial society (Audretsch 2014) and face growing pressure to take a more active role in developing new business activities to generate socioeconomic impact and become entrepreneurial universities (Foss and Gibson 2015; Urbano and Guerrero 2013). This is related to both educational and research activities, where the number of entrepreneurship education initiatives and the support infrastructure for science commercialization have expanded rapidly at universities worldwide (Kochenkova et al. 2016; Kuratko 2005). While the issues of entrepreneurship education and science commercialization have mainly been discussed separately, an emerging literature shows that these activities can be highly related (Marzocchi et al. 2017) and be key elements of an entrepreneurship education ecosystem (Belitski and Heron 2017). In fact, academic entrepreneurship is expanding to include wider benefits to the university ecosystem, for instance including students who start-up different business activities (Shah and Pahnke 2014; Siegel and Wright 2015b) and students enrolled in entrepreneurship education programs who can help commercialize science and technology (Martin and Karen 2015; Rasmussen and Sørheim 2006). Hence, in relation to university-based entrepreneurship, the educational and research-based roles of universities are converging.

University research constitutes a fertile source of entrepreneurial opportunities for developing new science and technology-based business activities (Shane 2000; Shane 2004). Because entrepreneurship education is an important activity to potentially raise individuals' awareness and attitudes towards entrepreneurial opportunities and develop entrepreneurial competences (Bae et al. 2014; Mwasalwiba 2010), there is considerable potential for linking entrepreneurship education and science commercialization at research-oriented universities (Boocock et al. 2009; Nelson and Byers 2015; Perkmann et al. 2013). In this regard, business schools and other university departments have increasingly started to provide specific science

and technology entrepreneurship education (STEE) (e.g., Hang et al. 2009; Markham et al. 2000; Mustar 2009). We define STEE as entrepreneurship education initiatives focusing on science commercialization and technology transfer processes. This definition goes beyond education provided as part of regular study programs and includes also extra-curricular initiatives and training initiatives of shorter duration, such as training programs, seminars and courses. Moreover, in terms of audience, STEE may be targeted not only to undergraduate students, but also to postgraduate students, PhD students, postdoctoral researchers, faculty members and technical support staff.

Developing educational resources for science commercialization is "not as simple as repacking an existing entrepreneurship or product development course" (Nelson and Monsen 2014: 774). It requires new approaches and contents because of the variety of activities, stakeholders and disciplines involved in science commercialization (e.g., Barr et al. 2009; Clarysse et al. 2009; Phan et al. 2009; Siegel 2009). Because of these complexities, scholars have questioned whether entrepreneurship education is sufficiently integrated with teaching and research in science and technology (Barr et al. 2009). In particular, we question whether STEE initiatives have been connected to other dedicated policies and structures that have been implemented to manage and facilitate the university technology transfer process (e.g., Geuna and Muscio 2009; Rasmussen et al. 2006).

A key infrastructure to facilitate science commercialization is the technology transfer offices (TTOs) that have been set up at most universities over the last few decades (Siegel and Wright 2015a; Weckowska 2015) to support the commercialization of research results through, e.g., the creation of spin-off firms, licensing and contracts with industry. University TTOs serve as boundary spanning organizations aiming to bridge the academic and business spheres (Huyghe et al. 2014, Villani et al. 2017). Indeed, policy reports emphasize the importance of integrating the TTO activities with the education and research missions of universities (Borlaug

et al. 2009; Debackere 2012). However, while the efforts of TTOs can be seen as complementary to educational programs in the area of STEE (e.g., Wright et al. 2009; Nelson and Monsen 2014), we know very little about the overall extent for TTO engagement in STEE. Moreover, TTOs are heterogeneous and differ in their maturity, organization and strategic orientation (Brescia et al. 2016; Lafuente and Berbegal-Mirabent 2018), which are likely to influence their involvement in STEE. Hence, we pose the following research questions: *To what degree does the involvement of TTOs in STEE depend on university and TTOs characteristics? What is the extent and scope of TTO involvement in STEE?*

This paper aims to map the involvement of European TTOs in STEE by looking at the prevalence, content and organization of such activities. We analyze a unique dataset collected through a survey, undertaken in the course of the Horizon 2020 project *X*[1], covering 176 university TTOs in 28 European countries. We examine the involvement of TTOs in STEE in terms of the scope of its contents (e.g., start-up formation, business planning, IPR protection, licensing), the target audiences (e.g., faculty, PhD students, undergraduates) and the efforts in term of duration. Our independent variables refer to key TTOs characteristics, such as age and strategic autonomy, and the strategic relevance of technology transfer activities for the university. To our knowledge, this is the first comprehensive mapping of university TTO involvement in STEE.

We find that the majority of TTOs (71 percent) are involved in STEE by participating in the delivery of (e.g., as speakers) and the organization of education initiatives, either alone or with other university departments. TTOs are often very involved in STEE, and we examine some of the conditions behind such involvement. At many universities, TTOs seem to be an integrated part of the entrepreneurship education ecosystem to develop entrepreneurial skills among both faculty and students. These findings provide an answer to calls for a greater

[1] Details of the project, not disclosed in this version of the manuscript to preserve anonymity, to be added later.

understanding of the intersection between entrepreneurship education and technology transfer and science commercialization (Mosey 2016; Nelson and Monsen 2014). This paper thus contributes to the literature on entrepreneurship education, TTOs and entrepreneurial universities by documenting the broader involvement of TTOs in STEE.

The remainder of the article is structured as follows. Next, we review the literature relating to university TTOs with particular emphasis on STEE activities and develop hypothesis related to our research questions. Then, the method section presents data concerning European university TTOs and the methods applied, followed by the findings. Finally, conclusions and implications are provided.

2. BACKGROUND

2.1. STEE and the role of TTOs

Science and technology entrepreneurship is increasingly considered a strategic asset for universities, often included in formal mission statements (Markman et al. 2005). Universities have been called on to reconcile the traditional scientific mission through dissemination mechanisms (i.e., publications) with the new commercial mission for the economic exploitation of their research results in the market (Rasmussen et al. 2006). In this scenario, teaching and learning technology commercialization is a requirement for supporting the Third Mission of the university, as it relies on "cooperation and coordination between service and academic departments working together on many different projects and on leveraging the goodwill and energy of students, staff and alumni" (Levie 2014: 807).

Technology transfer and science commercialization have an interdisciplinary nature (Schuelke et al. 1978), being characterized by a combination of science and technology, management, information science, and communication. Several studies argue for stronger connections among TTOs, business schools, hard-sciences/engineering schools, and science

parks/business incubators to promote technology transfer effectively at all levels, including professionals, academics, and students (Clarysse et al. 2009; Nelson and Monsen 2014). These characteristics have consequences for the design of effective science and technology entrepreneurship education (STEE) programs. First, STEE requires highly interdisciplinary programs and curricula in order to have a positive impact on people's perceptions of the multidisciplinary capabilities needed for technology transfer activities (Thursby et al. 2009). "From an educational standpoint, understanding translation science requires students to learn a new language that encompasses the scientific method, basic science, the law and legal strategy, business concepts, and market research tools" (Phan 2014: 810). In other words, education to improve science commercialization and technology transfer should integrate different sets of skills, notably business and science. Second, STEE requires a heterogeneity of approaches and of institutional arrangements to take place (Mok et al. 2010). In other words, the heterogeneity of STEE should reflect the heterogeneity of actors involved in the technology transfer activity. For instance, studies suggest that it is crucial to mobilize entrepreneurs and business people to involve them in STEE educational processes (Mustar 2009).

Following this reasoning, in this paper we focus on the role of TTOs, which have been set up with the mission to provide various support services for the commercialization of academic research, in the provision of STEE. Case examples report that TTOs can be key partners in STEE programs, particularly when students are developing real business cases to commercialize research findings (Barr et al. 2009; Rasmussen and Sørheim 2006). However, although a growing number of studies have analyzed (i) the role of TTOs in different types of commercialization mechanisms – patenting, licensing, spin-off creation, industry-university collaborations, contracts (Link and Scott 2005; Lockett and Wright 2005; Siegel et al. 2007) and (ii) the organizational structures typically adopted by TTOs (Bercovitz et al. 2001;

Debackere and Veugelers 2005; Markman et al. 2005) – literature has not explored the role of TTOs as providers of STEE.

We rely on the boundary spanning literature to explain the motivations behind TTO engagement in STEE. Boundary spanners can be defined as organizational actors that link agents that are distant from each other (Aldrich and Herker 1977; Williams 2002). The concept of distance can include various aspects, such as cognitive, geographical, organizational, and social distance (Villani et al. 2017). Independently from the type of distance considered, the literature suggests that boundary spanners are individuals or organizational units that take knowledge from one domain and apply it in another domain (Tushman and Scanlan 1981).

With this definition in mind, it is clear that TTOs, linking a scientific domain (i.e., university research) with a commercial domain (i.e., the market), can be considered as boundary spanners. Huyghe et al. (2014) labeled this bridging activity between "suppliers" of scientific research and "customers" as external boundary spanning. In addition, they introduced the concept of internal boundary spanning, considered an activity for managing internal knowledge and resource flows between different internal organizational units. In our context, this activity is crucial for helping researchers and entrepreneurs move along the complex technology transfer process. Examples of activities performed by TTOs as internal boundary spanners could be to communicate the university's strategic orientation and policy regarding technology transfer, to support the writing of proposals and business plans and to explain the role of TTOs in the valorization of academic research. However, few studies have investigated how TTOs operate in efficiently acting as boundary spanners (Comacchio et al. 2012). In this paper, we focus in particular on the internal dimension of boundary spanning to determine to what extent is the involvement of TTOs in STEE dependent on university and TTOs characteristics, and what is the extent and scope of TTO provision of STEE.

Starting from the idea that the presence of organizational boundaries is also associated with the existence of communication boundaries (Tushman and Scanlan 1981), we postulate that education can act as a mechanism for creating a common language understandable by all members of the university (i.e., faculty members, students, administrators, TTO staff). TTOs, being responsible for the valorization of academic research into the market, should have the competence to understand inventions and convert their academic value into commercial value. For this reason, TTOs may span boundaries effectively by obtaining information from one domain and disseminating it to another (Villani et al. 2017). A potentially powerful way of bridging between the scientific and the commercial domain is to provide education that generally enhances the competence among faculty and students. Hence, the provision of STEE would be complementary to the mission of TTOs as boundary spanners.

At the same time, literature has shown that TTOs are heterogeneous due to several institutional (university-level) and organizational (TTO-level) characteristics and practices, which have a key role on the performance and productivity of TTOs (e.g., Siegel et al. 2003; Siegel et al. 2007; O'Kane et al. 2015; Brescia et al. 2016; Lafuente and Berbegal-Mirabent 2018). Hence, we anticipate that these characteristics and practices could also affect the provision of STEE by TTOs. For these reasons, we are interested in understanding how (i) the age of the TTO as a measure of experience, (ii) the level of autonomy of the TTO and (iii) the importance of the Third Mission for the parent university can explain the scope of involvement of TTOs in STEE. In terms of the scope of involvement, we consider the breadth of contents covered by STEE, the different types of target audiences (e.g., faculty, PhD students, undergraduates) and the overall duration of STEE activities. In the next section, we discuss these factors in more detail and derive hypotheses to be tested in our study.

3. HYPOTHESES

Previous research has clearly documented the existence of significant differences among universities in the speed and extent of engagement in technology transfer activities (Siegel et al. 2007; Sine et al. 2003; O'Shea et al. 2005). This is also reflected in the heterogeneous levels of experience of their TTOs. For instance, according to the European Commission (2013), most university TTOs in Europe are still young, with half of them being established after 2000. The age of the TTO, as a measure of its level of experience, influences not only the types of operational activities it performs but also its ultimate outcomes. TTO age has been positively associated with the number of licensing agreements generated by universities (Conti and Gaule 2011), the number of research collaborations (Es-Sadki and Arundel 2015) and the involvement in gap funding activities through proof-of-concept programs or seed funds (Munari et al. 2015; Munari et al. 2017).

Regarding STEE, the age of the TTO can influence the scope of training activities for at least two sets of reasons. On the one hand, newly-established TTOs probably lack the resources and internal experience to directly promote training activities for faculty and students on a wide spectrum of topics. On the other hand, in the early phases, TTOs probably also lack the legitimacy and distinctive identity to be recognized as a credible partner within the university environment, traditionally focused on the two core missions of research and education. Indeed, O'Kane and colleagues (2015) shows that TTOs build legitimacy through a long, complex and deliberate process of identity shaping with academics and university management. Moreover, TTOs often develops from being a relatively isolated operation and become a more integrated and inclusive activity at universities over time (Debackere 2012).

Hence, it is likely that newly established TTOs initially are less engaged in STEE or focus their involvement on a narrow set of topics, reflecting their primary stakeholders (academic researchers) and areas of interest (typically, IPR protection issues) (Siegel et al. 2007). They

can eventually expand their involvement over time in terms of content (covering broader areas, such as commercialization, startup creation, access to finance) and target audiences (PhDs, postdocs, students). Consequently, we expect that:

Hypothesis 1. Older university TTOs have a broader scope of involvement in STEE than younger university TTOs.

The degree of strategic autonomy of the TTO is also an important factor influencing the modes of universities' engagement in technology transfer activities (Bercovitz et al. 2001; Markman et al. 2005; Siegel et al. 2003). Several studies have analyzed the causal link between the autonomy of the TTO and their performance (Bercovitz et al. 2001; Markman et al. 2005). Markman et al. (2005) interviewed 128 TTO directors in the United States and found that universities employ different TTO configurations with varying levels of autonomy. Their interviews highlighted that traditional, centralized TTOs may be subject to direct and often strong oversight by university administrations, thus limiting the autonomy of TTO management in matters of decision making, scope of activities, commercialization strategies, and incentive systems. In contrast, different organizational models characterized by independent units and separate budgets tend to have greater autonomy in defining strategies and operational activities.

Regarding STEE, the degree of decisional autonomy by the TTO is likely to impact the scope of training activity implemented by the university TTO for two main reasons. First, TTOs with higher autonomy levels are likely to have more degrees of freedom in the promotion of a broad spectrum of technology transfer activities, focusing not only on mere IPR protection issues but also on more commercially oriented exploitation activities. In this context, it is more important that faculty, young researchers and students acquire a broad set of competences in the technology transfer realm. Second, autonomous TTOs can more easily initiate new education initiatives, also in collaboration with other internal or external units. Hence, we argue

that TTOs with higher decisional autonomy with respect to the university administration can facilitate a broader set of STEE activities at the university level. Therefore, we hypothesize:

Hypothesis 2: University TTOs with a higher degree of strategic autonomy have a broader scope of STEE involvement than university TTOs with lower degree of strategic autonomy.

Finally, the strategic importance of the Third Mission for the parent university (D'Este and Patel 2007) may impact the way in which TTOs are involved in educational activity. Universities differ widely in their degree of commercial orientation, depending on for instance their founding mission (D'Este and Patel 2007), research orientation (Di Gregorio and Shane 2003), size and specialization (Munari et al. 2015). A growing literature has applied the notion of strategic orientation to describe the universities' involvement in technology transfer (Daraio et al. 2011; Feldman 2003). In this view, universities make strategic choices regarding institutional goals and priorities in technology transfer that drive decisions on resource allocation, activities and expected outcomes (Siegel et al. 2007).

This research suggests that universities that have deliberate policies and cultures that support commercialization will have higher levels of commercialization engagement and outcomes. Siegel (2013) highlighted the role of top-level university leaders in designing and implementing strategic initiatives that effectively deploy organizational resources towards entrepreneurial activities. Building on the dynamic capabilities framework, Leih and Teece (2016) discusses the two cases of Stanford and Berkeley to illustrate how, especially in the former case, the top-level strategies had a profound effect on the institution's general proclivity to sense and seize commercial opportunities. In a similar way, several accounts of universities' deliberate and strategic transitions towards the entrepreneurial model can be found in the literature (Etzkowitz et al. 2008; Jacob et al. 2003; O'Shea et al. 2005). While most universities

have set up a TTO, this is sometimes an isolated activity dealing with patents and licenses (Hülsbeck et al. 2013). The involvement of the TTO in STEE is likely to be higher if the TTO is seen as an inclusive activity at the university (Debackere 2012) that takes part in the entrepreneurship education ecosystem (Belitski and Heron 2017). Building on such insights, we can expect that a greater strategic importance assigned by universities to technology transfer activities is associated with broader involvement of TTOs in STEE. Therefore:

Hypothesis 3: University TTOs at universities placing a higher strategic relevance on technology transfer have a broader scope of STEE involvement than university TTOs at universities placing a lower strategic relevance on technology transfer.

4. RESEARCH DESIGN

4. 1. Sampling and data collection

The main data source for this paper is primary data collected through a survey distributed in 2015 to the population of 482 members associated with ASTP-Proton (the pan-European association for professionals involved in university-industry knowledge transfer)[2] and other national TTO associations, covering 27 European countries[3] plus Turkey. The survey was carried out in the course of the Horizon 2020 *X* project, in collaboration with the other project partners.[4]

The survey collected information on several dimensions of technology transfer activities inside public research organizations, such as the relationship between TTOs and parent organization, TTOs' structure, operations and training needs, and TT training provision at the organization. The survey was administered in two phases: First, paper copies of the survey were

[2] See ASTP-Proton website: http://www.astp-proton.eu/.
[3] Austria, Belgium, Croatia, Czech Republic, Cyprus, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Lithuania, Luxembourg, Malta, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Sweden, Switzerland, the Netherlands, and United Kingdom
[4] Details regarding the partners implementing the survey of TTO professionals to be disclosed in later version of the manuscript to preserve anonimity.

distributed to members present at the ASTP-Proton 2015 Annual Conference held in Istanbul. Second, the remaining TTOs were asked to complete an online survey electronically. Three email/phone recalls were carried out over a 3-month period. We obtained 195 questionnaires from 482 contacted TTOs, corresponding to a 40 percent response rate. Respondents were TTO directors (49.8 percent) or other TTO staff (50.2 percent) affiliated with research institutions in 28 European countries. Because we aim to investigate the provision of STEE by TTOs in academic institutions, we deleted those respondents from TTOs not affiliated with any tertiary education institutions listed in the European Tertiary Education Register (ETER)[5] (n=19), ending up with a final sample of 176 university TTOs in Europe. On average, the 176 TTOs in our sample were established in 2005 (*SD*=6.93) and employ 15 professionals (*SD*=25.65). The TTOs are located across Europe, with 19 percent in Northern Europe, 26 percent in Western Europe, 26 percent in Southern Europe, and 29 percent in Eastern Europe (details in Table A1). With respect to the non-respondent institutions, our sample is under-representative of institutions from Southern Europe ($p<0.01$) and over-representative of institutions from Eastern Europe ($p<0.01$). In addition, respondents are more likely to be institutions presenting high-level academic standards, being included in the Times Higher Education (THE) Ranking[6] ($p<0.01$). We therefore took into account the issue of response bias in our sample by correcting our empirical estimations through inverse probability weighting, as described in Section 4.3.

We complemented the survey data with secondary data on universities in the sample using the ETER and the THE Ranking and on the regions where they are located using Eurostat regional statistics[7].

[5] ETER (http://eter.joanneum.at/imdas-eter/) is a database currently providing detailed data on 2,465 higher education institutions in 32 European countries, implemented by the European Commission with the commitment of the national Ministers of Higher Education.

[6] The THE Ranking (https://www.timeshighereducation.com/) is a world university ranking that annually provides an evaluation of the world's best universities evaluated in terms of research, teaching, industry funding, international outlook and citations.

[7] Eurostat regional statistics (http://ec.europa.eu/eurostat/web/regions/statistics-illustrated) are offered by the European Commission to allow comparative analyses across European countries at the regional level based on NUTS classification. The current NUTS classification (released in 2013) lists 98 major socio-economic regions

4.2. Measurement

Dependent variables

This study considers three different dependent variables to study the scope of engagement of TTOs in STEE within European universities.

Scope of STEE contents: this variable is based on a survey question asking whether the training programs in STEE covered one or more of the following relevant topics: IPR protection, IPR and technology valuation, licensing, market and competitive assessment, research contract and industry consulting, start-up formation, business planning, access to finance, negotiation skills, and communication and presentation skills. Building on the responses to these items, we carried out a principal component factor analysis based on tetrachoric correlation matrix and using oblique promax rotation, which revealed four factors related to major content areas (see Table A2 for more details). We identified the four factors as follows: "IPR management" (including IPR protection, IPR and technology valuation, and communication and presentation skills); "Market and strategy" (including market and competitive assessment; business planning; negotiation skills); "Commercialization of research" (including licensing and research contract and industry consulting); and "Start-up development" (including start-up formation and access to finance). We then created dummy variables related to each of the four factors to identify whether the TTO was involved in teaching any of them. Finally, we constructed an ordinal categorical variable with five categories measuring the scope of content areas covered by STEE programs (0 = no training program offered; 1 = training in only one content area; 2 = training in two content areas; 3 = training in three content areas; 4 = training in four content areas). This ordered categorical

(NUTS 1), 272 basic regions for the application of regional policies (NUTS 2), and 1,342 small regions for specific diagnoses (NUTS 3).

variable is used as the first dependent variable in our analyses to capture the scope of TTO involvement in STEE in terms of content.

Scope of STEE target audience: we built this variable from a survey question asking what is the targeted audience for seminars and courses in STEE, with options including one or more among the following: faculty members, PhD students and postdoctoral researchers, master students and/or other students, technical/support staff, and others (which respondents identified as industry people). Each choice was coded as a dummy variable. We then created an ordinal categorical variable with five categories measuring the number of different audiences targeted by TTO training in STEE (0 = no training program offered; 1 = only one type of audience; 2 = two types of audiences; 3 = three types of audiences; 4 = four or more types of audiences).

Scope of STEE effort: this variable is based on a survey question asking respondents to indicate the approximate number of hours of seminar/courses in STEE organized by the TTO in 2014, with the following options: less than 5 hours, 5-10 hours, 10-20 hours, 20-40 hours, 40-60 hours, and more than 60 hours. We created an ordinal categorical variable with six categories measuring the scope of STEE effort in terms of hours spent providing training (0 = no training program offered; 1 = 1-10 hours; 2 = 11-20 hours; 3 = 21-40 hours; 4 = 41-60 hours; and 5 = more than 60 hours).

Independent variables

Our first independent variable at the TTO level is *TTO age,* computed as the number of years from the TTO's establishment to 2015. Second, we constructed a variable referring to *TTO strategic autonomy*, building on a survey question asking how the TTO defined its strategic priorities vis-à-vis the parent university. We operationalized it as a dummy variable equaling 1 for TTOs whose strategic priorities are jointly set by the TTO and the university top management (and 0 in cases where the strategic priorities are defined only by the university top

management). Our third independent variable accounts for parent university strategic commitment to technology transfer. It is based on a question asking whether TT activities are part of the university strategic plan, with the following response options: I do not know; the university does not have a formalized strategic plan; the PRO has a strategic plan but TT activities are not mentioned in it; the university has a strategic plan, and TT activities are mentioned in it; and the university has a strategic plan, and TT activities are an important component of it. We thus constructed a dummy variable *University TT relevance* with a value of 1 if the university has a strategic plan and TT activities are an important part of it (0 otherwise).

Control variables

Our estimations include a set of control variables identified from our review of the literature as potentially influencing the breadth of TTO involvement in training activities on TT topics at three different levels: the TTO level, the university level, and the regional level.

At the TTO level, the involvement of TTOs in the organization and delivery of STEE training could be determined by the existence of incentive schemes for the staff and/or management of the TTO. We therefore use the control *TTO incentives*, measured as a dummy variable with a value of 1 if the university adopts such incentive schemes and 0 otherwise. We additionally include the measure of *TTO size*, which we operationalize as the number of employees working in the TTO in 2014 (in logarithm).

At the university level, we control for *University age*, measured as the number of years from establishment to 2015. We add a dummy variable called *Generalist university* that assumes a value of 1 for generalist universities identified in the ETER dataset (the variable "Institutional Category Standardized") and 0 for other universities (e.g., universities of applied sciences, medical schools, engineering schools, or polytechnics). Additionally, TTOs

embedded in universities with a hospital might present different patterns of training, so we include a dummy variable *University hospital* equal to 1 if the university has a hospital and 0 otherwise. We then measure university prestige with the dummy variable *High-quality university*, assuming the value 1 if the university was one of the 400 top academic institutions in the world in 2014 as calculated by the Times Higher Education (THE) Ranking; and 0 otherwise. Being included in the THE Ranking signals an overall high quality with respect to research, industry funding, international outlook and citations. We introduce two further variables related to specific commercialization activities carried out by the university. *University incubator* was measured as a dummy variable equaling 1 when there is an incubator inside the university for supporting start-up formation and 0 otherwise. *Proof-of-concept (POC) funding* was operationalized as a dummy variable equaling 1 when the PRO had a POC funding program in place for supporting inventors to further develop and validate their technologies and 0 otherwise.

At the regional level, we use two control variables accounting for information about the regions where universities are located, drawing on Eurostat statistics. Specifically, we introduce *Regional innovation*, measuring the expenditure on research and development by private enterprises as a percentage of regional GDP, and *Regional size*, measuring the logarithm of the population in 2014.

A summary of all the variables employed for our analyses is found in Table 1.

Insert Table 1 about here

4.3. Empirical model

Our dependent variables are ordered categories of increasing TTO involvement related to the scope of content, audience, and effort of STEE activities. We therefore analyze our data using ordered logit models. Ordered logit models are based on the cumulative probabilities of the

response variable; in particular, the logit of each cumulative probability is assumed to be a linear function of the covariates with regression coefficients constant across response categories. Ordered logit is therefore a regression model appropriate for an ordered probability variables (Greene 1997). Because ordered probit is also an appropriate model to analyze our data, we choose ordered logit because the two specifications lead to trivial differences in cross-sectional studies (Greene 1997).

Our ordered logit estimations include a correction for response bias using inverse probability weighting (Wooldridge 2007). We proceed in two steps. First, we run a probit regression to estimate whether or not a university TTO responded to our survey, using three dummy variables for the university's geographical area (Eastern, Western, and Northern Europe) and research quality in terms of THE Ranking (Table 2). Based on the results of this probit, we calculate weights for each observation as the inverse of its predicted values. Second, we run our main ordered logit regressions by weighting observations through the inverse probability scores calculated in the first step.

Insert Table 2 about here

---

5. RESULTS

5.1. Descriptive results

According to the survey responses, 125 out of 176 universities (71 percent) offer some kind of training programs on issues related to science and technology entrepreneurship, organized with the direct involvement of the TTO. This evidence shows that STEE has become a widely diffused and important component of universities' engagement in Third Mission activities. It also confirms that STEE represents an important area of activity for the vast majority of TTOs

at European universities, consistent with the role of the TTO as a boundary spanner that we discussed in the theoretical section of the paper. Table 3 presents some examples of training programs promoted by university TTOs, often in collaboration with other university partners or external partners. The table illustrates a wide variety of programs, ranging from short seminars on issues mostly focused on IPR protection and valorization, to intensive entrepreneurship programs spanning over several months.

Table 4 shows that IPR protection represents the topic most frequently covered by the courses mentioned in the survey (94 percent of the TTOs engaged in STEE activities cover that topic). Other frequently taught topics in STEE include start-up formation (64 percent of cases), licensing (50 percent) and research contracts and industry consulting (49 percent). The results of our principal component analyses are consistent with the findings. The topics included under the "IPR management" content area are the most prevalent (100 percent), followed by those related to "Start-up development" (71 percent), "Commercialization of research" (66 percent) and "Market and strategy" (55 percent). On average, TTOs providing STEE cover at least two content areas (Table 5).

Insert Table 3, Table 4 and Table 5 about here

Table 6 shows that the majority of TTOs engaged in STEE (64 percent) offer training for several different audiences. According to the survey responses, most TTOs carry out training activities targeting doctoral and post-doctoral researchers (90 percent) and faculty members (82 percent). Students (62 percent) and technical/support staff (29 percent) represent target audiences with a smaller presence in this context. A very limited number of TTOs offer training courses also targeting private companies (4 percent). On average, TTOs involved in STEE activities serve at least two types of audiences (Table 6).

Insert Table 6 about here

Table 7 shows that TTOs have different degrees of involvement in terms of number of training hours concerning STEE. The TTOs providing some type of training are engaged in 11-20 hours on average (Table 7). Hence, such training programs are characterized by a limited duration, although approximately one-fifth of them are involved in more than 40 hours of training.

Insert Table 7 about here

Besides the dimensions of training breadth illustrated above, the survey also assessed other interesting dimensions regarding the engagement of TTOs in STEE, which allow us to gain a more comprehensive picture of TT training activities. For instance, the involvement of TTOs can range from being solely invited as speakers (10 percent) to organizing courses autonomously (68 percent) in collaboration with other university departments/schools (66 percent) or in collaboration with external stakeholders (e.g., public authorities, consulting companies, national technology transfer associations) (56 percent).

In addition, the survey showed that the number of participants in STEE courses offered by TTOs ranges from fewer than 10 (4 percent), 11-30 participants (18 percent), 31-50 participants (26 percent), or 51-100 participants (24 percent) to more than 100 participants (29 percent). On average, TTOs reach 11-50 participants through such courses.

Finally, through the survey we also obtained some insights about training assessment practices at TTOs. The majority of TTOs implement some form of assessment of the training they provide (76 percent). Generally, these assessments regard the degree of participants'

satisfaction (58 percent) or participation rate (50 percent), whereas a minority of TTOs assess the effectiveness of training in terms of subsequent engagement of participants in TT activities or practical application of lessons learned (26 percent).

5.2. Results of the regression analyses

Correlations across variables are shown in Table 8, while analyses from ordered logit regression are reported in Table 9.

Insert Table 8 and Table 9 about here

Hypothesis 1 stated that older TTOs have a broader scope of involvement in STEE. Our regression results show *TTO age* positively and significantly impacts the involvement of TTO in the STEE with regard to the scope of training content ($p<0.05$) and the scope of the targeted audience ($p<0.05$). However, we do not find support that *TTO age* has an impact on the scope of training effort in terms of hours of education delivered.

Hypothesis 2 claimed that the higher the degree of decisional autonomy of a university TTO, the broader the scope of its involvement in STEE. We found a positive and significant effect of *TTO strategic autonomy* on the scope of TTO involvement in STEE with regard to the scope of training content ($p<0.05$) and the scope of targeted audience ($p<0.05$).

Hypothesis 3 stated that the higher the strategic relevance of technology transfer is for the university, the broader the scope of TTO involvement in STEE. We found support for this hypothesis because *University TT strategic relevance* has a positive and significant effect on the scope of TTO involvement in STEE with regard to the scope of training content ($p<0.05$), targeted audience ($p<0.05$), and training effort ($p<0.05$).

Regarding the control variables, we found a negative and significant effect of TTO size on the scope of TTO involvement in STEE related to the scope of training content and audience (p<0.05). This finding appears counterintuitive because it would suggest that larger TTOs have a narrower focus with regard to STEE contents and audiences. We advance three possible explanations. First, some TTOs are large because they are established to serve more than one university – for example, being constituted as regional bodies supporting the TT activities of universities and other public research organizations located in the region. Second, smaller TTOs may focus more efforts on education because they need to increase their legitimacy within their organizations through wide-reaching activities such as STEE. Third, it might be that larger TTOs are located at larger universities that have other organizational units providing STEE. However, because we were not able to find reliable data about these two characteristics for the entire sample (particularly for universities in Eastern Europe and Turkey), we think that further investigation of this issue is needed. We also found that TTOs located in universities having an incubator (p<0.01) or proof-of-concept funding (p<0.05) have broader involvement in STEE activities. This is an interesting result, showing that involvement in STEE is associated with wider entrepreneurial engagement of the parent university and of the TTO.

6. DISCUSSION AND CONCLUSION

In order to contribute to societal and economic development, universities are increasing their commitments towards science- and technology-based entrepreneurship, in particular, through the provision of STEE and the development of TTOs. Although these two mechanisms are recognized by the literature as critical factors for improving science-based entrepreneurship, until now they have been analyzed separately (Nelson and Monsen 2014). Our paper provides a novel view of the entrepreneurship education ecosystem by examining the role of TTOs in the provision of STEE. Our findings, based on a unique dataset covering 176 TTOs across

Europe, show that TTOs are key actors in the delivery of STEE and that the scope of their involvement – in terms of contents, target audiences, and effort – is broader for older, more autonomous TTOs located in universities placing high strategic relevance on technology transfer activities.

This paper adds both to the literature on how and by whom STEE is delivered and to the literature on the role and operation of TTOs. By assessing the link between TTOs and entrepreneurship education, we gain further insight into the operation of entrepreneurial universities (Audretsch, 2014). We discuss the specific contributions below.

First, this study extends the growing literature on entrepreneurship education (Bae et al. 2014; Fayolle 2013; Rasmussen and Sørheim 2006) that has mainly dealt with initiatives offered to traditional students, typically as part of formal study programs. The provision of education to foster university technology transfer has been comparatively overlooked by academic studies. Importantly, this paper moves beyond policy reports and studies focused on a single country, seldom offering cross-country comparisons (e.g., Francis-Smythe et al. 2006; Woolgar 2006). Most entrepreneurship education is offered by business schools, with limited linkages to the science and engineering departments where most university technologies originate. However, as noted by Siegel and Phan (2005), there is a need to address the skill deficiencies among university faculty, administrators and other actors involved in academic entrepreneurship. Some studies have indicated an important role of business schools, asserting that there is a need for better linkages between business knowledge and the TTOs and academic scientists (Wright et al. 2009). Despite some pioneering initiatives where entrepreneurship students are involved in the commercialization of research through the creation of spin-off firms based on university research (Boh et al. 2016; Rasmussen and Sørheim 2006), there seems to be a large potential for integration between STEE and technology transfer (Nelson and Monsen 2014). Our findings suggest that TTOs and their staff provide significant contributions to the

delivery of entrepreneurship training and education. These findings can represent a platform for future studies connecting TTO performance and involvement in STEE and their training needs and learning practices (e.g., Weckowska 2015). Moreover, we observe that TTOs typically deliver STEE in collaboration with other actors within or external to the university. Hence, TTOs may not only serve as boundary spanners between research and business but they may also integrate educational initiatives in the STEE ecosystem.

The widespread use of TTOs in STEE may also stem from the need to incorporate a combination of practical and academic skills in entrepreneurship education (Moroz et al 2010). Indeed, many entrepreneurship programs and courses involves a large share of practitioners. Our findings may reflect an increasing use of action-oriented education initiatives (Rasmussen and Sørheim 2006), where students are involved in learning-by-doing initiatives such as case studies, games, projects, simulations, real-life actions, internships with start-ups and other activities involving interaction with entrepreneurs (Markuerkiaga 2016). For educators, the TTO may be a valuable partner for providing a more practice oriented content in entrepreneurship education.

Second, we investigated the key role played by the TTO as a boundary spanner able to reach and involve different actors in the technology transfer process (Huyghe et al. 2014). More precisely, we assert that STEE education provided by TTOs may be an effective way to reach such an integration among different levels of the university ecosystem, which can lead to increased contacts and stimulate technology transfer activity (Villani et al. 2017). Indeed, close partnerships between the TTOs and the educational process as well as close linkages between disciplines (science, engineering, business, law and others) are key factors for understanding and leveraging the broader university commercialization ecosystem.

The role of TTOs seems to be developing over time, from a relatively narrow focus on IP protection and generating revenue from selling university inventions towards a broader role in

fostering entrepreneurial activities based on scientific knowledge (Debackere 2012). Our findings provide compelling evidence on the level of engagement by TTOs in activities outside of traditional core activities. Several studies have indicated that TTOs play a more limited role for science commercialization than is typically assumed because a significant share of university commercialization bypasses the TTO (Fini et al. 2010) and the majority of scientists lacks awareness of the TTO's existence (Huyghe et al. 2016). Our findings show that the TTO may have a broader role by not only addressing specific licensing and spin-off topics but also engaging in competence-building activities into a variety of topics with many actors involved in technology transfer.

The fact that most European TTOs are involved in the provision of STEE is a clear sign that TTOs are not isolated entities working solely to maximize the income from university patents. Many TTOs seem to be broadly engaged in enhancing the university capabilities for science-based entrepreneurship, which would involve increased competence at all levels in the university organization (Bienkowska et al. 2016; O'Shea et al. 2007). This broader engagement seems to be part of a trend where TTOs have developed from being relatively isolated operations to becoming a more integrated activity at many universities (Debackere 2012). Although our data are cross sectional, the fact that older TTOs are more engaged in STEE indicates that TTO operations evolve over time into a more legitimate and integrated activity in the entrepreneurial university (O'Kane et al. 2015).

Third, our study adds to the literature on entrepreneurial universities by exploring how TTOs are involved in competence-enhancing activities. We find that TTOs' engagement in STEE is correlated with other initiatives, such as university incubators and proof-of-concept programs (Baraldi and Havenvid 2016). Hence, the involvement in STEE may indicate that the TTO is part of a broader entrepreneurial ecosystem for science commercialization consisting of many initiatives. Therefore, the determinants of TTO engagement in STEE may be linked to

factors at the university, regional and national levels. Many universities have an entrepreneurial system where different groups in the university and the region provide a fruitful environment for science commercialization (Jacob et al. 2003; O'Shea et al. 2007). Moreover, many countries have set up government support programs for developing infrastructure and training initiatives for university technology transfer (Rasmussen et al. 2008).

Although the involvement of TTO professionals in STEE programmes is reasonable and valuable, as previously explained, it could create also downsides which need to be taken into consideration. First, TTO members have the capabilities to pool innovations across research labs and to valorize these innovative researches, but as teaching is not their primary activity, they may suffer of limited experience and capabilities. This lack risks to initiate a "vicious circle" of "training the trainer" where TTO professionals need to be coached in order to be able to manage educational activities with consequent deficiencies in the process. Second, it is well known the technology transfer is composed of two dimensions – science and market – which need to be integrated. An excessive emphasis on the market, supported by practice-based trainings, could excessively shift the attention of scholars towards the commercial dimension, at the expense of the primary objective of doing high-quality research. Finally, from an organizational point of view, the involvement of TTO professionals in STEE activities asks for the need to develop a collaborative system, where different actors – university administrative staff, TTO professionals and faculty members – do not invade areas of expertise of others in the decision-making process, but harmoniously cooperate in the definition of valuable STEE programmes.

Our study suffers of some limitations which needs to be pointed out for suggesting future areas of research. A first limitation of this study is that we cannot document any causal linkages between TTO engagement in STEE and university performance in technology transfer. However, the widespread practice of STEE involvement by European TTOs leads us to suggest

that the role of TTOs might be broader than typically assumed. Indeed, it has been shown that the establishment of TTOs is not by itself sufficient to generate high-growth new businesses from university research (Fini et al. 2017), and the attitudes and engagement of scientists are much more important for commercialization than the assistance provided by the TTO (Wu et al. 2015). Hence, our findings support the concept that TTOs play an important role as intermediary organizations helping to reduce the cognitive and organizational distance between academia and industry (Villani et al. 2017). By being involved in STEE, the role of TTOs in increasing university technology transfer is more indirect and broader than is typically measured (Moroz et al. 2010), and new indicators are required to assess TTO productivity (Gulbrandsen and Rasmussen 2012; Resende et al. 2013).

Another limitation of our study is that we use relatively few TTO- and university-level dimensions (i.e., TTO age and autonomy, strategic relevance of technology transfer in the university) to explain TTOs involvement in STEE. More fine-grained results could be obtained by investigating additional variables, such as the specific profiles and academic background of the TTO professionals, their connection to university departments, or their motivations to be involved in STEE activities; or undertaking studies about the processes through which TTOs come to be seen as credible, attractive, or powerful partners in lecturing STEE for academics. Hence, we invite scholars to undertake future studies assessing how different actors contribute to an entrepreneurship education ecosystem and the impacts of STEE to enhance entrepreneurial competencies at various levels in the university organization and surrounding ecosystem.

Finally, our data do not allow to better differentiate among different types of education: a seminar is different from a training program and a course aimed at faculty members may resemble more to train-the-trainer courses instead of student education. The course designs could also be very different. An analysis of this heterogeneity may be extremely valuable for

understanding the real positioning of TTOs in the STEE landscape and further highlight elements of complementarity among different offers.

REFERENCES

Aldrich, H., & Herker, D. (1977). Boundary spanning roles and organization structure. Academy of Management Review, 2(2), 217-230.

Audretsch, D. B. (2014). From the entrepreneurial university to the university for the entrepreneurial society. The Journal of Technology Transfer 39 (3), 313-321.

Bae, T. J., Qian, S., Miao, C., & Fiet, J. O. (2014). The Relationship Between Entrepreneurship Education and Entrepreneurial Intentions: A Meta-Analytic Review. Entrepreneurship Theory and Practice, 38(2), 217-254.

Baraldi, E., & Havenvid, M. I. (2016). Identifying new dimensions of business incubation: A multi-level analysis of Karolinska Institute's incubation system. Technovation, 50, 53-68.

Barr, S. H., Baker, T., Markham, S. K., & Kingon, A. (2009). Bridging the Valley of Death: Lessons Learned From 14 Years of Commercialization of Technology Education. Academy of Management Learning & Education, 8(3), 370-388.

Belitski, M., & Heron, K. (2017). Expanding entrepreneurship education ecosystems. Journal of Management Development, 36(2), 163-177.

Bercovitz, J., Feldman, M., Feller, I., & Burton, R. (2001). Organizational structure as a determinant of academic patent and licensing behavior: An exploratory study of Duke, Johns Hopkins, and Pennsylvania State universities. The Journal of Technology Transfer, 26(1), 21–35.

Bienkowska, D., Klofsten, M., & Rasmussen, E. (2016). PhD Students in the Entrepreneurial University - Perceived Support for Academic Entrepreneurship. European Journal of Education, 51(1), 56-72.

Boh, W. F., De-Haan, U., & Strom, R. (2016). University technology transfer through entrepreneurship: faculty and students in spinoffs. The Journal of Technology Transfer, 41(4), 661-669.

Boocock, G., Frank, R., & Warren, L. (2009). Technology-Based Entrepreneurship Education: Meeting Educational and Business Objectives. The International Journal of Entrepreneurship and Innovation 10 (1), 43-53.

Borlaug, S. B., Grünfeld, L., Gulbrandsen, M., Rasmussen, E., Rønning, L., Spilling, O. R., et al. (2009). Between entrepreneurship and technology transfer: Evaluation of the FORNY programme. In Report 19 (pp. 160). Oslo: NIFU STEP.

Brescia, F., Colombo, G., & Landoni, P. (2016). Organizational structures of Knowledge Transfer Offices: an analysis of the world's top-ranked universities. The Journal of Technology Transfer, 41(1), 132-151.

Clarysse, B., Mosey, S., & Lambrecht, I. (2009). New trends in technology management education: A view from Europe. Academy of Management Learning and Education, 8(3), 427-443.

Comacchio, A., Bonesso, S., & Pizzi, C. (2012). Boundary spanning between industry and university: the role of Technology Transfer Centres. The Journal of Technology Transfer, 37(6), 943-966.

Conti, A., & Gaule, P. (2011). Is the US outperforming Europe in university technology licensing? A new perspective on the European Paradox. Research Policy, 40(1), 123-135.

Daraio, C., Bonaccorsi, A., Geuna, A., Lepori, B., Bach, L., Bogetoft, P., & Fried, H. (2011). The European university landscape: A micro characterization based on evidence from the Aquameth project. Research Policy, 40(1), 148-164.

D'Este, P., & Patel, P. (2007). University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry? Research Policy, 36(9), 1295-1313.

Debackere, K. (2012). The TTO: a university engine transforming science into innovation. LERU – League of European Research Universities Advice Paper n. 10, available at https://lirias.kuleuven.be/bitstream/123456789/364034/1/2012-11-05, accessed 6 June 2017.

Debackere, K., & Veugelers, R. (2005). The role of academic technology transfer organizations in improving industry science links. Research Policy, 34(3), 321–342.

Di Gregorio, D., & Shane, S. (2003). Why do some universities generate more start-ups than others? Research Policy, 32(2), 209-227.

Es-Sadki, N., & Arundel, A. (2015). The impact of the regional environment on the knowledge transfer outcomes of public research organisations: preliminary results for Europe. Working paper n. #2015-017, UNU Merit Working Paper Series, Maastricht Economic and social Research institute on Innovation and Technology (UNU-MERIT) & Maastricht Graduate School of Governance (MGSoG).

Etzkowitz, H., Ranga, M., Benner, M., Guaranys, L., Maculan, A. M., Kneller, R. (2008). Pathways to the entrepreneurial university: towards a global convergence. Science and Public Policy, *35*(9), 681-695.

European Commission (2013). European Knowledge Transfer Report 2013. Knowledge Transfer Study 2010-2012, Final Report – Deliverable 5, June 2013. Available at https://ec.europa.eu/research/innovation-union/pdf/knowledge_transfer_2010-2012_report.pdf, accessed 6 June 2017.

Fayolle, A. (2013). Personal views on the future of entrepreneurship education. Entrepreneurship & Regional Development, 25(7-8), 692-701.

Feldman, M.P. (2003). Entrepreneurship and American research universities: evolution in technology transfer. In D. M. Hart (Ed.), The Emergence of Entrepreneurship Policy: Governance, Start-ups, and Growth in the U.S. Knowledge Economy (pp. 92-112). Cambridge: Cambridge University Press.

Fini, R., Lacetera, N., & Shane, S. (2010). Inside or outside the IP system? Business creation in academia. Research Policy, 39(8), 1060-1069.

Fini, R., Fu, K., Mathisen, M. T., Rasmussen, E., & Wright, M. (2017). Institutional determinants of university spin-off quantity and quality: a longitudinal, multilevel, cross-country study. Small Business Economics, 48(2), 361-391.

Foss, L., & Gibson, D. v. (2015). The Entrepreneurial University: Context and Institutional Change: Routledge.

Francis-Smythe, J., Haase, S., Steele, C., & Jellis, M. (2006). Competencies and Continuing Professional Development (CPD) for Academics in Knowledge Exchange (KE) Activity. CONTACT Knowledge Exchange.

Geuna, A., & Muscio, A. (2009). The Governance of University Knowledge Transfer: A Critical Review of the Literature. Minerva 47 (1), 93-114.

Greene, W.H. (1997). Econometric Analysis (Third Edition). London: Prentice-Hall

Gulbrandsen, M., & Rasmussen, E. (2012). The use and development of indicators for the commercialisation of university research in a national support programme. Technology Analysis & Strategic Management, 24(5), 481-495.

Hang, C. C., Ang, M., Wong, P. K., & Subramanian, A. M. (2009). Technology management educational initiatives in Asia: A case study from the National University of Singapore. Academy of Management Learning & Education, 8(3), 444-456.

Hülsbeck, M., Lehmann, E. E., & Starnecker, A. (2013). Performance of technology transfer offices in Germany. The journal of technology transfer, 38(3), 199-215.

Huyghe, A., Knockaert, M., Piva, E., & Wright, M. (2016). Are researchers deliberately bypassing the technology transfer office? An analysis of TTO awareness. Small Business Economics, 47(3), 589-607.

Huyghe, A., Knockaert, M., Wright, M., & Piva, E. (2014). Technology transfer offices as boundary spanners in the pre-spin-off process: the case of a hybrid model. Small Business Economics, 43(2), 289-307.

Kochenkova, A., Grimaldi, R., & Munari, F. (2016). Public policy measures in support of knowledge transfer activities: a review of academic literature. The Journal of Technology Transfer 41 (3), 407-429.

Kuratko, D. F. (2005). The Emergence of Entrepreneurship Education: Development, Trends, and Challenges. Entrepreneurship Theory and Practice 29 (5), 577-598.

Jacob, M., Lundqvist, M., & Hellsmark, H. (2003). Entrepreneurial transformations in the Swedish University system: the case of Chalmers University of Technology. Research Policy, 32(9), 1555-1568.

Lafuente, E., & Berbegal-Mirabent, J. (2018) Assessing the productivity of technology transfer offices: an analysis of the relevance of aspiration performance and portfolio complexity. The Journal of Technology Transfer, 1-24. In press.

Leih, S., & Teece, D. (2016). Campus leadership and the entrepreneurial university: A dynamic capabilities perspective. The Academy of Management Perspectives, 30(2), 182-210.

Levie, J. (2014). The university is the classroom: teaching and learning technology commercialization at a technological university. The Journal of Technology Transfer, 39(5), 793-808.

Link, A. N., & Scott, J. T. (2005). Opening the ivory tower's door: An analysis of the determinants of the formation of US university spin-off companies. Research Policy, 34(7), 1106–1112.

Lockett, A., & Wright, M. (2005). Resources, capabilities, risk capital and the creation of university spin-out companies. Research Policy, 34(7), 1043–1057.

Markham S, Baumer, D. Aiman-Smith, L, Kingon, K. & Zapta M. (2000). An Algorithm

of High Technology Engineering and Management Education. Journal of Engineering Education, 89, 209-218

Markman, G., Phan, P., Balkin, D., & Giannodis, P. (2005) Entrepreneurship and University-Based Technology Transfer. Journal of Business Venturing, 20(2), 241-263.

Markuerkiaga, L., Caiazza, R., Igartua, J. I., & Errasti, N. (2016). Factors fostering students' spin-off firm formation: an empirical comparative study of universities from North and South Europe. Journal of Management Development, 35(6), 814-846.

Martin, L., & Karen, W. M. (2015). Venture creation programs: bridging entrepreneurship education and technology transfer. Education + Training 57 (1), 48-73.

Marzocchi, C., Kitagawa, F., & Sánchez-Barrioluengo, M. (2017). Evolving missions and university entrepreneurship: academic spin-offs and graduate start-ups in the entrepreneurial society. The Journal of Technology Transfer.

Mok, M.S., Sohn, S.Y., & Ju, Y.H. (2010). Conjoint analysis for intellectual property education. World Patent Information, 32, 129–134

Moroz, P. W., Hindle, K., & Anderson, R. (2010). Collaboration with entrepreneurship education programmes: building spinout capacity at universities. International journal of innovation and learning, 7(3), 245-273.

Mosey, S. (2016). Teaching and research opportunities in technology entrepreneurship. Technovation, 57, 43-44.

Munari, F., Pasquini, M., & Toschi, L. (2015). From the lab to the stock market? The characteristics and impact of university oriented seed funds in Europe. The Journal of Technology Transfer, 40(6), 948-975.

Munari, F., Sobrero, M., & Toschi, L. (2017). Financing technology transfer: assessment of university-oriented proof-of-concept programmes. Technology Analysis & Strategic Management, 29(2), 233-246.

Mustar, P. (2009). Technology management education: Innovation and entrepreneurship at MINES ParisTech, a leading French Engineering School. Academy of Management Learning and Education, 8(3), 418-425.

Mwasalwiba, E. S. (2010). Entrepreneurship education: a review of its objectives, teaching methods, and impact indicators. Education+ Training, 52(1), 20-47.

Nelson, A.J., & Monsen, E. (2014). Teaching technology commercialization: introduction to the special section. Journal of Technology Transfer, 39, 774-779.

Nelson, A., & Byers, T. (2015). Challenges in University Technology Transfer and the Promising Role of Entrepreneurship Education. The Chicago Handbook of University Technology Transfer and Academic Entrepreneurship, 138.

O'Kane, C., Mangematin, V., Geoghegan, W., & Fitzgerald, C. (2015). University technology transfer offices: The search for identity to build legitimacy. Research Policy, 44(2), 421-437.

O'Shea, R. P., Allen, T. J., Chevalier, A., & Roche, F. (2005). Entrepreneurial orientation, technology transfer and spinoff performance of US universities. Research policy, 34(7), 994-1009.

O'Shea, R. P., Allen, T. J., Morse, K. P., O'Gorman, C., & Roche, F. (2007). Delineating the anatomy of an entrepreneurial university: the Massachusetts Institute of Technology experience. R & D Management, 37(1), 1-16.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., & Krabel, S. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. Research Policy, 42(2), 423-442.

Phan, P.H. (2014). The business of translation: The Johns Hopkins University Discovery to Market program. Journal of Technology Transfer, 39, 809–817.

Phan, P. H., Siegel, D. S., & Wright, M. (2009). New developments in technology management education: Background issues, program initiatives, and a research agenda. Academy of Management Learning & Education, 8(3), 324-336.

Rasmussen, E., Borch, O. J., & Sørheim, R. (2008). University entrepreneurship and government support schemes In A. Fayolle & P. Kyrö (Eds.), The Dynamic between Entrepreneurship, Environment and Education (pp. 105-130). Cheltenham: Edward Elgar.

Rasmussen, E., Moen, O., & Gulbrandsen, M. (2006) Initiatives to promote commercialization of university knowledge. Technovation, 26(4), 518–533.

Rasmussen, E., & Sørheim, R. (2006). Action-based entrepreneurship education. Technovation, 26(2), 185-194.

Resende, D. N., Gibson, D., & Jarrett, J. (2013). BTP—Best Transfer Practices. A tool for qualitative analysis of tech-transfer offices: A cross cultural analysis. Technovation, 33(1), 2-12.

Schuelke, L.D., Dbsedel, J.A., & Bond, D.G. (1978). A pilot survey of courses in technology transfer offered at selected colleges and universities in the United States. Journal of Technology Transfer, 2(2), 53-69.

Shah, S. K., & Pahnke, E. C. (2014). Parting the ivory curtain: understanding how universities support a diverse set of startups. The Journal of Technology Transfer 39 (5), 780-792.

Shane, S. (2000). Prior Knowledge and the Discovery of Entrepreneurial Opportunities. Organization Science 11 (4), 448-469.

Shane, S. (Ed.). (2004). Academic entrepreneurship -University spinoffs and wealth creation. Cheltenham: Edward Elgar Publishing, Inc.

Siegel, D. (2009). From the guest editors: New developments in technology management education. Academy of Management Learning and Education, 8(3), 321–323.

Siegel, D. S., & Phan, P. H. (2005). Analyzing the effectiveness of university technology transfer: Implications for entrepreneurship education. In G. D. Libecap (Ed.), University entrepreneurship and technology transfer: Process, design, and intellectual property (Vol. 16, pp. 1-38). Oxford: Elsevier.

Siegel, D. S., Veugelers, R., & Wright, M. (2007). Technology transfer offices and commercialization of university intellectual property: performance and policy implications. Oxford Review of Economic Policy, 23(4), 640-660.

Siegel, D. S., Waldman, D., & Link, A. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study. Research Policy, 32(1), 27-48.

Siegel, D. S., & Wright, M. (2015a). University technology transfer offices, licensing, and start-ups. In A. Link, D. S. Siegel & M. Wright (Eds.), Chicago handbook of university technology transfer and academic entrepreneurship (Vol. Forthcoming). Chicago, IL: University of Chicago Press.

Siegel, D. S., & Wright, M. (2015b). Academic Entrepreneurship: Time for a Rethink? British Journal of Management 26 (4), 582-595.

Sine, W. D., Shane, S., & Gregorio, D. D. (2003). The halo effect and technology licensing: The influence of institutional prestige on the licensing of university inventions. Management Science, 49(4), 478-496.

Thursby, M.C., Fuller, A.W., & Thursby, J. (2009) An Integrated Approach to Educating Professionals for Careers in Innovation. Academy of Management Learning & Education, 8(3), 389-405.

Tushman, M.L., Scanlan, T.J. (1981) Boundary spanning individuals: their role in information transfer and their antecedents. Academy of Management Journal, 24(2), 289-305.

Urbano, D., & Guerrero, M. (2013). Entrepreneurial Universities: Socioeconomic Impacts of Academic Entrepreneurship in a European Region. Economic Development Quarterly 27 (1), 40-55.

Villani, E., Rasmussen, E., & Grimaldi, R. (2017). How intermediary organizations facilitate university–industry technology transfer: A proximity approach. Technological Forecasting and Social Change, 114, 86-102.

Weckowska, D. M. (2015). Learning in university technology transfer offices: Transactions-focused and relations-focused approaches to commercialization of academic research. Technovation, 41, 62-74.

Williams, P. (2002). The competent boundary spanner. Public administration, 80(1), 103–124.

Wooldridge, J. F. (2007). Inverse probability weighted estimation for general missing data problems. Journal of Econometrics, 141(2), 1281-1301.

Woolgar, L. (2006). A comparative assessment of training courses for knowledge transfer professionals in the United Stated, United Kingdom and Japan. Working Paper No. 42.

Wright, M., Piva, E., Mosey, S., & Lockett, A. (2009). Academic entrepreneurship and business schools. The Journal of Technology Transfer, 34(6), 560-587.

Wu, Y., Welch, E. W., & Huang, W. L. (2015). Commercialization of university inventions: Individual and institutional factors affecting licensing of university patents. Technovation, 36, 12-25.

EXHIBITS

Table 1 Measurement of variables

#	Variable name	Description	Data source
Dependent variables			
1	Scope of STEE content	0 = no training program offered 1 = training on only one content area 2 = training on two content areas 3 = training in three content areas 4 = training in four content areas	Survey
2	Scope of STEE audience	0 = no audience 1 = only one type of audience 2 = two types of audiences 3 = three types of audiences 4 = four or more types of audiences	Survey
3	Scope of STEE effort	0 = no training 1 = 1-10 hours 2 = 11-20 hours 3 = 21-40 hours 4 = 41-60 hours 5 = more than 60 hours	Survey
Independent variables			
4	TTO age	Number of years since establishment	Survey
5	TTO strategic autonomy	1 = strategic priorities jointly set by the TTO and university management; 0 otherwise	Survey
6	University TT relevance	1 = TT activities are an important component of university strategic plan; 0 otherwise	Survey
Control variables			
7	TTO size	Logarithm of the number of TTO employees	Survey
8	TTO incentive	1 = incentive schemes for TTO employees; 0 otherwise	Survey
9	University age	Year of establishment of the parent university	ETER
10	Generalist university	1 = generalist university; 0 otherwise	ETER
11	University hospital	1 = presence of a hospital in the university; 0 otherwise	ETER
12	High-quality university	1 = the university is part of THE Ranking institutions; 0 otherwise	THE Ranking
13	University incubator	1 = the university has an incubator in 2014; 0 otherwise	Survey
14	POC funding	1 = the university has a POC funding scheme in place in 2014; 0 otherwise	Survey
15	Regional innovation	Expenditure on research and development by private enterprises as a percentage of regional GDP	Eurostat
16	Regional size	Logarithm of the population in 2014	Eurostat

Table 2 Probit regression of the probability of being a respondent of the survey

Variables	Response
Eastern Europe	1.183***
	(0.186)
Western Europe	0.223
	(0.158)
Northern Europe	-0.0591
	(0.172)
Ranking high quality university	0.525***
	(0.141)
Constant	-0.738***
	(0.108)
Observations	482

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3 Examples of training programs in STEE promoted by TTOs of European Universities

Country	University	TTO involved*	Name of the training program	Target Audience	Main contents of the training program	Length
Belgium	University of Ghent	UGent TechTransfer	Introduction to technology transfer skills	UGhent researchers, including post-docs and PhDs	Funding of valorisation projects; R&D and licensing contracts; patents and other IPRs; commercial strategy and market assessment; Marketing the technology	5 days course
Belgium	KU Leuven	KU Leuven Research & Development (LRD)	Training course on knowledge & technology transfer	Doctoral and post-doctoral researchers of all disciplines	Three major themes: collaboration with industry; patenting and licensing; creating a spinoff company	5 days course
Ireland	University College Dublin	UCD Innovation	UCD Startup Stars	UCD undergraduate and postgraduate students from all disciplines	Entrepreneurship programme including cross-disciplinary workshops and course modules (such as Business Model Canvas, Revenue Model and Pricing, Funding Strategy and Sources, Building the Team, etc)	Intensive 4-week programme
Italy	University of Trento	Research Support and Knowledge Transfer Division	Crash Course in Intellectual Property Protection and Valorization	The seminars are open to doctoral students, undergraduate and master students, researchers and private companies	Seminars covering the following topics: Patenting process and regulations, copyright protection, technology assessment and exploitation, industry collaborations	A series of 7 seminars (2 hours each)
Netherlands	Utrecht University	Utrecht Holdings	Selling your Science	PhD, post-docs, (senior) researchers	Six topics: Value of research; Entrepreneurship; Conflict of interest; IPRs; Negotiation; Pitching	Two day course
Portugal	University of Minho	TechMinho	IdeaLab	Undergraduate, Master and PhD students, senior researchers	Business Idea Laboratory, including a set of workshops and training events (i.e. Voice of the Customer, Market Assessment, Strategy, Finance for Startup, Pitching Ideas)	Programme spread over 4 months

Sweden	Lund University	LU Innovation	Commercialise your research	Doctoral students	Focus on the entrepreneurial process, including how to identify a business opportunity, design a business model, perform a market analysis, manage IPRs and financing	A course of 7.5 credits
UK	Imperial College	Imperial Innovations	Innovation Academy	Anyone with an interest in forming a science-based company (including researchers and students)	A programme of courses on technology entrepreneurship and commercialisation (including introduction to IP, spinout fundamentals, sales and marketing, building an effective team, finance for startups, etc…)	A set of 12 training events (typically, 1/2 day each)
* The TTO could be involved as a partner in the organisation of the course, together with other University units or external actors						

Table 4 Topics covered during the seminar and courses organized by TTO

Description	N	Percent
IPR protection	118	94.40
IPR and technology valuation	54	43.20
Communication and presentation skills	29	23.20
IPR management	**125**	**100.00**
Market and competitive assessment	31	24.80
Business planning	59	47.20
Negotiation skills	19	15.20
Market and strategy	**69**	**55.20**
Licensing	63	50.40
Research contract and industry consulting	61	48.80
Commercialization of research	**83**	**66.40**
Start-up formation	80	64.00
Access to finance	40	32.00
Start-up development	**89**	**71.20**

Note: n=125 TTOs involved in any type of TT training at the parent PRO

Table 5 Scope of STEE content

Description	N	Percent
(0) No training program offered	51	28.98
(1) Training in only one content area	11	6.25
(2) Training in two content areas	26	14.77
(3) Training in three content areas	49	27.84
(4) Training in four content areas	39	22.16
Total	**176**	**100.00**

Table 6 Scope of STEE target audience

Description	N	Percent
(0) No training program offered	51	28.98
(1) Training to one type of audience	13	7.39
(2) Training to two types of audiences	36	20.45
(3) Training to three types of audiences	54	30.68
(4) Training to four or more types of audiences	22	12.50
Total	**176**	**100.00**

Table 7 Scope of STEE effort

Description	N	Percent
(0) No training program offered	51	28.98
(1) 1-10 hours	25	14.20
(2) 11-20 hours	33	18.75
(3) 21-40 hours	27	15.34
(4) 41-60 hours	16	9.09
(5) More than 60 hours	24	13.64
Total	**176**	**100.00**

Table 8 Correlations across variables

		Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Scope of STEE content	2.08	1.55	1														
2	Scope of STEE audience	1.90	1.43	0.828*	1													
3	Scope of STEE effort	2.02	1.75	0.761*	0.723*	1												
4	TTO age	10.18	6.93	0.078	0.036	-0.081	1											
5	TTO strategic autonomy	0.68	0.47	0.469*	0.413*	0.301*	-0.07	1										
6	University TT relevance	0.33	0.47	0.222*	0.243*	0.192*	0.028	0.149*	1			-						
7	TTO incentive	0.28	0.45	-0.024	0.025	0.049	-0.098	-0.103	0.094	1								
8	TTO size	2.26	0.92	-0.033	-0.068	0.032	0.261*	0.042	0.063	0.214*	1							
9	University age	157.16	209.55	0.064	-0.024	-0.023	0.227*	0.051	-0.081	-0.133	-0.041	1						
10	Generalist university	0.92	0.27	0.097	0.024	0.124	-0.050	0.021	-0.062	-0.048	-0.007	0.089	1					
11	University hospital	0.40	0.49	0.123	0.056	0.096	0.157*	0.148*	-0.084	-0.030	0.061	0.283*	0.242*	1				
12	High quality university	0.38	0.49	0.043	-0.029	-0.010	0.251*	0.043	0.098	-0.027	0.155*	0.263*	0.187*	0.309*	1			
13	University incubator	0.53	0.5	0.388*	0.351*	0.338*	0.036	0.343*	0.057	0.015	0.131	0.065	-0.067	-0.035	-0.056	1		
14	POC funding	0.35	0.48	0.311*	0.326*	0.333*	-0.043	0.223*	0.201*	0.124	0.220*	-0.162*	0.126	0.107	0.142	0.210*	1	
15	Regional innovation	1.07	0.57	-0.006	-0.025	-0.031	0.277*	0.060	0.041	-0.158*	-0.233*	0.059	-0.017	0.147	0.180*	-0.088	0.073	1
16	Regional size	14.77	0.85	0.004	0.081	0.073	-0.135	0.074	-0.007	0.232*	0.085	-0.011	-0.258*	0.034	-0.054	0.181*	0.035	-0.365*

N=176

* $p<0.05$

Table 9 Results from ordered logit regression

Variables	DV: Scope of STEE content	DV: Scope of STEE audience	DV: Scope of STEE effort
TTO age	0.07**	0.06**	0.02
	(0.027)	(0.028)	(0.028)
TTO strategic autonomy	1.33**	1.11**	0.73
	(0.524)	(0.520)	(0.465)
University TT relevance	0.93**	0.81**	1.07**
	(0.396)	(0.399)	(0.442)
TTO incentive	0.22	0.32	0.24
	(0.526)	(0.429)	(0.439)
TTO size	-0.63***	-0.73***	-0.30
	(0.230)	(0.251)	(0.225)
University age	0.00	-0.00	0.00
	(0.001)	(0.001)	(0.001)
Generalist university	0.95	0.26	1.28**
	(0.582)	(0.546)	(0.650)
University hospital	0.26	-0.02	0.09
	(0.401)	(0.387)	(0.382)
High quality university	-0.59	-0.38	-0.32
	(0.381)	(0.452)	(0.402)
University incubator	1.12***	1.27***	1.15***
	(0.401)	(0.414)	(0.365)
POC funding	1.09***	1.01**	1.04**
	(0.407)	(0.467)	(0.420)
Regional innovation	0.23	0.72	0.83
	(0.609)	(0.515)	(0.589)
Regional size	-0.15	0.18	-0.04
	(0.304)	(0.328)	(0.267)
Eastern Europe	0.77	0.25	0.50
	(0.544)	(0.483)	(0.476)
Western Europe	0.01	-0.71	-0.70
	(0.831)	(0.711)	(0.846)
Northern Europe	-0.10	-0.56	-1.05
	(0.669)	(0.779)	(0.673)
Observations	176	176	176
Pseudo R-squared	0.149	0.137	0.109

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

APPENDIX

Table A1 Location of sampled TTOs per country

Country	N	Percent	Macro-area
Austria	9	5.11	Western Europe
Belgium	2	1.14	Western Europe
Croatia	1	0.57	Eastern Europe
Cyprus	1	0.57	Southern Europe
Czech Republic	8	4.55	Eastern Europe
Denmark	7	3.98	Northern Europe
Estonia	2	1.14	Eastern Europe
Finland	2	1.14	Northern Europe
France	17	9.66	Western Europe
Germany	10	5.68	Western Europe
Hungary	5	2.84	Eastern Europe
Iceland	1	0.57	Northern Europe
Ireland	4	2.27	Northern Europe
Italy	25	14.2	Southern Europe
Lithuania	1	0.57	Eastern Europe
Luxembourg	1	0.57	Western Europe
Malta	1	0.57	Southern Europe
Norway	3	1.7	Northern Europe
Poland	7	3.98	Eastern Europe
Portugal	3	1.7	Southern Europe
Serbia	4	2.27	Eastern Europe
Slovenia	1	0.57	Eastern Europe
Spain	15	8.52	Southern Europe
Sweden	3	1.7	Northern Europe
Switzerland	2	1.14	Western Europe
The Netherlands	5	2.84	Western Europe
Turkey	22	12.5	Eastern Europe
United Kingdom	14	7.95	Northern Europe
Total	**176**	**100.00**	

Table A2 Factor analysis, STEE contents provided by TTOs

Item	Factor1 IPR management	Factor2 Market and strategy	Factor3 Commercialization of research	Factor4 Start-up development	Uniqueness
IPR protection	**0.9651**				0.0989
IPR and technology valuation	**0.6582**				0.486
Communication and presentation skills	**-0.5900**				0.319
Market and competitive assessment		**0.9192**			0.1989
Business planning		**0.5731**			0.1538
Negotiation skills		**0.8385**			0.1671
Licensing			**0.7387**		0.2765
Research contract and industry consulting			**0.9104**		0.1536
Start-up formation				**0.9592**	0.1494
Access to finance				**0.6082**	0.3262