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Engines need transmission belts: the importance of people in technology transfer offices

Alessandra Micozzi[1,2] · Donato Iacobucci[3] · Irene Martelli[4] · Andrea Piccaluga[4]

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Abstract

Over the last 20 years, universities and Public Research Organizations have increased their efforts to transfer their research results towards industrial applications in order to generate economic and social impact. Among many different actions, new technology transfer offices (TTOs) have been set up and existing ones strengthened. The present paper intends to evaluate the effects of a specific policy action launched by the Italian Patent and Trademark Office (UIBM) within the Italian Ministry of Economic Development (MISE), aimed at increasing the number of employees in TTOs to foster technology transfer in general and the valorization of intellectual property rights more specifically. Our results suggest that the impact of the UIBM policy action has been positive and that in some specific situations the impact was stronger. Our results therefore contribute to the technology transfer literature and can have implications for both academic research and decisions regarding investments in human resources in university TTOs.

Keywords Spin-offs · Technology transfer · Technology transfer office · Human resources · Italy

JEL Codes O30 · O38 · C54

✉ Alessandra Micozzi
a.micozzi@univpm.it

Donato Iacobucci
d.iacobucci@univpm.it

Irene Martelli
irene.martelli@santannapisa.it

Andrea Piccaluga
a.piccaluga@santannapisa.it

1 Università E-Campus, Via Isimbardi, Novedrate, Italy

2 Center of Innovation and Entrepreneurship, Università Politecnica Delle Marche, Via Brecce Bianche, 1, Ancona, Italy

3 Università Politecnica delle Marche, Via Brecce Bianche, 1, Ancona, Italy

4 Istituto di Management, Scuola Superiore Sant'Anna, Piazza Martiri della Libertà, Pisa, Italy

1 Introduction

The creation of new scientific knowledge and its valorization to create economic and social impact through new products, services and processes represent crucial challenges in both advanced and emerging economies. It is not surprising, therefore, that currently there is much discussion among scholars and policy makers about the Third Mission of universities and the design and implementation of policy actions aimed at supporting knowledge transfer activities (Guimón and Paunov 2020).

However, knowledge transfer is an extremely complex and multifaceted process (Bradley et al. 2013) of which University Technology Transfer Offices (TTOs) are commonly recognized as an important component, albeit not the only one (Holgersson and Aaboen 2019), even if some scholars are skeptical about their contribution (Goldfarb and Henrekson 2003; Krücken et al. 2007; Muscio 2010; Saragossi and van Pottelsberghe de la Potterie 2003).

Countries like the US, UK and Israel have a longer tradition in this field, and the situation is not homogeneous in the rest of the world. In Italy, for example, it is only since the early 2000s that universities and other PROs have started to set up TTOs and have been gradually reinforcing them.[1] In 2017 the average number of people employed in Italian university TTOs[2] was around five (Ramaciotti and Daniele 2018), which is still far less than the number observed in most of the other European countries (Van Looy et al. 2011; ASTP 2019). However, after 2005 Italian universities have systematically invested in TTOs, hiring specialized people (Algieri et al. 2013; Bigliardi et al. 2015). This strengthening process of TTOs has been constant but not very rapid, due to budget constraints in universities and to their different degrees of commitment to Third Mission activities.

In 2015, the Italian Patent and Trademark Office (UIBM), which operates within the Italian Ministry of Economic Development (MISE), introduced measures to strengthen university TTOs.[3] The aim of these measures was to increase the intensity and effectiveness of technology transfer processes, with positive consequences for Italian universities and, at the same time, for Italian companies, the most direct "beneficiaries" of UIBM-MISE actions. Such a scheme was funded on a 50/50 basis by UIBM-MISE and applicant universities and consisted in hiring people in university TTOs. The new employees were hired in most cases with temporary contracts and were usually young, with a PhD in STEM disciplines; even if not extremely skilled in TT, they represented a remarkable increase in the total number of TT professionals in Italian universities.

Some scholars are skeptical about the role played by TTOs and do not consider the efforts of universities in terms of financial and human resources to support them as

[1] Normally, the quality of TTOs grows with age, since employed managers improve their skills with experience and training, even if, in some cases, people mobility may strengthen or weaken such learning processes.

[2] In the Netval survey this also includes PROs and research hospitals.

[3] The UIBM-MISE action is aimed at increasing the innovative capacity of companies, in particular small and medium-sized ones, facilitating the absorption and further development of scientific-technological knowledge in specific production sectors and local contexts. The UIMB-MISE action finances the realization of projects that aim to increase the intensity and quality of the TT processes from universities and PROs to companies by strengthening TTO staff and their skills. Concretely, a number of PROs have presented a specific project and have co-financed 50% of the inclusion of new people in their TTOs (the other 50% has been financed by the UIBM). The resources dedicated to the UIBM-action in 2015 amounted to 3 million euros.

fundamental for technology transfer activities (Fini et al. 2009; Meoli and Vismara 2014). Other studies, however, argue that TTOs are useful and try to understand the conditions that make them more effective (Finne et al. 2009; Finne et al. 2011; Rossi and Rosli 2015; Lafuente and Berbegal-Mirabent 2019). According to the findings of such literature, relevant issues include the position of TTOs in the organization, their mission, the level of empowerment by the university top management and the level of staff with regard to both competences and numbers.

As a matter of fact, there is empirical evidence showing a significant relationship between the number of people employed in the TTOs and TT outcomes, such as the number of new spin-off companies and licensed patents (Cartaxo and Godinho 2017; Chapple et al. 2005; Hülsbeck et al. 2011; Kergroach et al. 2018; Smilor and Matthews 2004; Vohara et al. 2004). These results are challenged not only by those who are skeptical about TTOs' importance, but also by those who do not support the need to increase TTO staff, arguing that the quality of employees is more important than their quantity (Bart Clarysse et al. 2011). Indeed, only skilled and experienced TTOs can effectively support technology transfer activities (Hulsbeck et al. 2013; Smilor and Matthews 2004; Visintin and Pittino 2014; Vohara et al. 2004; Clarysse et al. 2011). We therefore identified the UIBM action in Italy as an interesting setting to test some of the contrasting hypotheses debated in the literature.

Given the recent implementation of the policy action, we are able to explore the short-term impact of this kind of policy on TT activities (i.e. a two year period). Furthermore, beyond our main research issue about the effect of having more people in the TTOs, we consider the size of this effect, whether it is larger in small, medium or large universities, if it is larger when the TTO grows by + 1, + 2 o + 3 staff and finally, how the effect changes on the basis of the starting dimension of the TTO.

Following Tseng and Raudensky (2014), to evaluate the impact of the action, we used several metrics of TTO performance, which include the number of invention disclosures, the number of patent applications, the number of granted patents, income from royalties, the number of licensing agreements and the number of academic spin-offs.

Our results show that even in the short term the effect of additional staff in TTOs is clear and significant for both the identification of inventions and other technology transfer mechanisms, such as the number of licenses. The effect is less significant when we consider the creation of new spin-offs or licensing revenues which are likely to be observed after a longer period of time.

The paper is organized as follows. In Sect. 2 we examine the literature related to our research questions and specify the hypotheses that will be tested in the empirical section. Section 3 contains a description of the dataset and of the methodology adopted to address our hypotheses. Section 4 is devoted to the empirical findings and the analysis of the results. The last section provides some conclusive remarks.

2 Literature review

The competitiveness of countries in the global economy depends extensively on scientific, technological and innovation-based assets. Unfortunately, several studies show that even in an advanced area like Europe the flow of results of public research towards industrial applications is not without obstacles. Evidence exists about the continuation of the well-known "European Paradox", according to which Europe suffers from a gap between high levels of scientific performance and lower levels of contributions to economic competitiveness, especially with regard to high-tech sectors and new innovative start-ups (Dosi et al. 2006; Rodríguez-Navarro and Narin 2018). As a consequence, extensive work has been addressed to these issues at different European levels, including attention to university TTOs, that have the role of carrying out the central task of bringing research results towards industrial application (Barra and Zotti 2018; Hayter et al. 2018).

Since the mid-1990s, universities worldwide have been increasingly involved in the valorization of their research results, which includes both commercialization and other activities generating economic and social impact. As a consequence, the phenomenon of entrepreneurial universities has received considerable attention due to the fact that the entrepreneurial orientation of universities can provide valuable contributions to the knowledge-based economy (Bathelt et al. 2010; Budyldina 2018; Jain et al. 2009; Lazzeroni and Piccaluga 2003). In such a framework, most universities have adopted specific strategic guidelines to generate impact and establish TTOs with the aim of facilitating knowledge transfer through several channels, including licensing to industry (Siegel et al. 2003; Jonkers and Sachwald 2018), the creation of spin-off companies, etc. As a matter of fact, much of the debate among scholars and policy makers is not if universities should get involved in knowledge transfer, but rather about how they should do it.

For example, in the context of academic entrepreneurship, the empirical literature focuses on the factors that motivate academics to establish spin-offs (Fini et al. 2008); the characteristics of spin-offs and their growth processes (Chiesa and Piccaluga 2000; Iacobucci et al. 2011; Vanaelst et al. 2006), the composition of the promoting team and its impact on performance (Vanaelst et al. 2006; Ben-Hafaïedh et al. 2018), the academic fields of invention disclosures (Geuna and Nesta 2006; Thursby et al. 2001), and the effect of the Bayh-Dole Act in providing incentives for universities to increase patenting in fields in which licensing is an effective mechanism for acquiring new technical knowledge (Shane 2004a, b). More generally, a very interesting issue is why some universities are more successful in valorization processes than others. Several authors have tried to understand this topic for patenting (Siegel et al. 2007), licensing (Shane 2004a, b; Siegel et al. 2007) or spin-offs (Clarysse et al. 2007; Gras et al. 2008).

Within this literature, TTOs are often mentioned for their role in the process (Finne et al. 2011; Lafuente and Berbegal-Mirabent 2019). In fact, they contribute to the decision of whether or not to patent an invention, they interact with researchers and advise them about TT issues, they organize training in the field of TT and entrepreneurship, they maintain contact with industrial partners, they take care of licensing activities, etc. TTOs are expected to be responsible for the generation of results in terms of patents/licenses and spin-off companies and they are often assessed using indicators built with these outputs. However, despite the broad range of their activities, different views exist about the relevance of their role. Gerbin and Drnovsek (2016) in a systematic analysis and synthesis of 135 articles published between 1980 and 2014, showed that the majority of empirical studies find a positive relationship between the size of TTOs and the amount of disclosed inventions, patents, licenses, spin-offs and licensing revenue (Thursby et al. 2001, Powers 2004, Owen-Smith and Powell 2001, Carlsson and Fridh 2002, Siegel et al. 2003, Lach and Schankerman 2004, Chapple et al. 2005, Markman et al. 2005, Arundel et al. 2013). However, this result is not universally supported. Thursby and Thursby (2002) find that the rapid expansion of TTOs can also negatively affect licensing productivity. Arundel et al. (2013) in their report about knowledge transfer in Europe, find that the size of TTOs has a significant and positive impact on the number of invention disclosures, license agreements, license income and start-ups. On the other hand, however, Chapple et al. (2005) find that in UK universities the larger and older TTOs appear to be less efficient than younger and smaller ones if the number of licensing agreements is considered as an outcome of TT.. Lach and Schankerman (2004), who analyzed 102 US universities, find no evidence of a relationship between the size of a TTO and its success in terms of licensing revenue.

Lafuente and Berbegal-Mirabent (2019) analyzing the productivity level of TTO in Spanish universities, also find that the size of TTOs is not significant.

In the following section we propose a TT process that starts from invention disclosures, that are an important precursor of university licensing (Xu et al. 2011), and can then proceed to patents, licenses or to the setting up of new firm (academic spin-offs).

2.1 Invention disclosures

It is widely accepted that the activities and quality of a university TTO "at least partly shape the decision of faculty whether to engage in invention disclosure. Efficient and well-staffed TTOs have been identified as instrumental for inducing high quality invention disclosures" (Walter et al. 2018, p. 1731).

Disclosures are definitely influenced by the number of full-time equivalent personnel in the TTO (Thursby and Thursby 2002) as well as by the quality of the staff, since they normally interact with academics and this is likely to determine more participative behaviors on their part, such as disclosing their inventions to the TTO (Thursby et al. 2001).

In general, less than half of the inventions with commercial potential are disclosed (Thursby et al. 2001) and TTOs often report that "convincing faculty to disclose inventions is one of our major problems" (Thursby and Thursby 2002, p. 2). Accordingly, Siegel et al. (2003), based on interviews with several faculty members, confirm that in the US many academics do not disclose inventions to their universities. Recently, a survey of the Association of University Technology Managers (AUTM) found that licensing agreements, invention disclosures, and patent applications have increased: in 2015, 6680 U.S. patents were issued, generating around 30 billion USDs in net product sales (AUTM 2017; Backs et al. 2019).

With the abolition of the professors' privilege in many European countries a relevant increase in university licensing and patenting has been observed (Backs et al. 2019). Some authors argue that a strong and competent TTO can improve this process, creating a shared entrepreneurial culture and better supporting and engaging those researchers who have obtained interesting inventions.

Sellenthin (2009) explores the topic of patenting in relation with TTOs, comparing Sweden and Germany. The quantitative analysis of his survey shows the positive impact of support infrastructures towards patenting and incentive bonuses linked to third mission activities such as lectures, consulting or patenting, while Hulsbeck et al. (2013) using the number of invention disclosures as a performance measure of TTOs, find no effect of TTO size for German universities.

Della Malva et al. (2013), analyze the effects of the Innovation Act introduced by the French government in 1999 with the aim of fostering the commercialization of academic inventions, and demonstrate a positive effect of the presence of a TTO.

Xu et al. (2011) show that TTO size is positively and significantly correlated with the number of invention disclosures, due to the fact that TTO staff can engage faculty members and share with them information about the importance of the invention disclosure process. Carlsson and Fridh (2002) also found that the number of invention disclosures was an increasing function of total research expenditures and the size of the TTO staff.

In the Italian context the introduction of the so called Third Mission of universities, which refers to the wide range of activities and channels through which universities have a positive impact on society, is a relatively recent phenomenon, at least in comparison to other advanced countries. Italian TTOs have been growing in the last ten years and they have also contributed to spreading the culture of the valorization of research results, including the diffusion of practices about invention disclosures.

According to George et al. 2005, "perceived social and economic enablers, institutional support and perceived impediments play a significant role in the willingness of scientists to adopt an entrepreneurial role to identity and engage in technology commercialization activity, measured by the level of invention disclosure".

Our expectation is therefore that:

Hp1 An increase in the number of employees in TTOs will have a positive impact on the number of identified inventions.

2.2 Patents and licenses

Coupé (2003) shows that universities with a TTO will have a higher expected number of patents than universities without a TTO and that the effect of the TTO increases over time. Arvanitis et al. (2008) concluded that the presence of TTOs is one of the main determinants of patenting. Several authors also find that TTO staff size has a positive impact on the number of licenses (Foltz et al. 2000; Thursby and Kemp 2002). Ustundag et al. (2011), confirming that human resources are a very influential factor for TTO performance, suggest that TTOs may need to be reconfigured into smaller units, since there may be scope for the development of sectors in which local systems may be specialized. In this sense, an improvement in the performance of university TTOs may require the creation of smaller, more specialized TT units within universities, rather than just increasing the size of technology transfer offices per se. Chapple et al. (2005) find that TTOs in the UK exhibit a low level of absolute efficiency in licensing activity and that the growth in the size of TTOs has not been accompanied by a growth in the business skills and capabilities of TTO managers.

Another stream of literature found that larger TTOs are less efficient than smaller ones (Thursby and Kemp 2002). A possible explanation for this is provided by Heisey and Adelman (2011), who show that TTO size could be a substitute for early entry. In fact, as TTOs increase their experience, it might be possible that "learning by doing" results in greater ability to achieve objectives or to have better performance without increasing staff size.

Other studies in Europe do not confirm the positive impact of TTO activities in promoting and valorizing the commercialization of academic research (see Goldfarb and Henrekson 2003 for Sweden; Krücken et al. 2007 for Germany; Muscio 2010 for Italy; Saragossi and van Pottelsberghe de la Potterie 2003 for Belgium; Sellenthin 2009 for Germany and Sweden). Thursby and Thursby (2002) even find a negative association between TTO growth and the growth of number of licenses, which should suggest that rapidly expanding TTOs may exhibit lower productivity, because they may lose familiarity and proximity with the faculty. Other studies discuss the low efficiency of TTOs, which are even sometimes perceived as obstacles in knowledge transfer processes rather than facilitators (Clarysse et al. 2005;Bradley et al. 2013; Fini et al. 2011; Meoli and Vismara 2016). Van Looy et al. (2011), Siegel et al. (2003) and Lach and Schankerman (2004) find that the relation between TTO size and invention disclosing, patenting and licensing is not significant.

In the Italian context, the number of patents is influenced, among other factors, by the strategies adopted and the funding made available by universities. Furthermore, recent works (Campbell et al. 2020), appear not to include patents among knowledge transfer indicators. We therefore chose to use the number of licenses as indicators of TTO performance, since it identifies the patents that have been concretely involved in the development process towards application in the market. The licensing process is extremely complex and hardly manageable by a researcher without the intervention of the TTO.

Despite the presence of some controversial results in the literature, and considering the characteristics of the Italian context, we tested the following hypothesis:

Hp2 An increase in the number of employees in TTOs will have a positive impact on the number of licenses.

With regard to licensing revenue, results are also controversial. Siegel et al. (2003) show that TTO staff size doesn't increase licensing revenues, whereas other authors found that increasing staff size within a TTO increased the expected licensing revenue for the university (Heysey and Adelman 2011). Thursby et al. (2001) show a significant effect of TTO staff size on increasing licensing agreements, and a significant effect of increasing licensing agreements on increased royalties, even if the authors do not test a direct effect of TTO staff size on royalties.

Moreover, in the empirical analysis we are only able to analyze the short-term effects of TTO enlargements (over a two-years basis). This time period is sufficient to observe an impact on inventions, patents and licenses, while the effect on license revenues is likely to be observed in a longer time span.

Therefore, we will test the following hypothesis:

Hp3 An increase in the number of employees in TTOs will have no effect on license revenues.

2.3 Academic spin-offs (ASOs)

With regard to the creation of ASOs, academic entrepreneurs often lack the management skills to evaluate the market potential of their ideas, to write a business plan, get in touch with financial and industrial partners, etc.; TTOs can help them in these activities and can also help ASOs in attracting high-profile human resources (Colombo and Piva 2008). Some studies (Algieri et al. 2013) show that the availability of financial resources and highly skilled employees are crucial for ASO activities (Gras et al. 2008) and well-staffed TTOs can increase the quality of the services provided by a university TTO (Lockett and Wright 2005a; Smilor and Matthews 2004; Vohara et al. 2004). The factor that appears most relevant for spin-off creation and performance is the presence of qualified employees, which is more important than the absolute number of employees in TTOs (Hulsbeck et al. 2013; Lockett et al. 2005; Smilor and Matthews 2004; Vohara et al. 2004; O'Shea et al. 2005), but the experience of the TTOs (Friedman and Silberman 2003), with staff composed of people who have marketing, technical and negotiation skills (Siegel et al. 2003; Lockett and Wright 2005a, b; O'Shea et al. 2005), is also relevant to foster the creation of ASOs.

Caldera and Debande (2010) show that the size of TTOs has a positive and significant impact on the creation rate of spin-offs. Other authors also find that larger TTOs generate more technology transfer outcomes (Lockett and Wright 2005b; O'Shea et al. 2005;

Powers and McDougall 2005; Siegel et al. 2003). In larger TTOs, for example, it is possible to hire employees with specific expertise and skills.

According to the literature, we therefore propose the following hypothesis:

Hp4 An increase in the number of employees in TTOs will have a positive impact on the creation of spin-offs.

3 Data and methodology

The UIBM policy action represents a sort of a controlled experiment to explore the effects of a sudden and relevant increase in the number of people employed in TTOs. We therefore decided to exploit this situation to test the hypotheses about the relations between employees in TTOs and technology transfer outcomes. To this aim we collected data about the new people employed in Italian university TTOs, which was the immediate effect of the UIBM action. Not all universities took advantage of the opportunity offered by UIBM to strengthen their TTOs; this allowed us to compare the treated universities against the non-treated ones.

Data about universities and TTOs were collected from several sources. Data and information about ASOs were collected from a database jointly developed by the Center for Innovation and Entrepreneurship of the Università Politecnica delle Marche and the Institute of Management at the Scuola Superiore Sant'Anna, in collaboration with Netval.[4] The database contains information about the characteristics of Italian ASOs—i.e. name, year of foundation, university of foundation, sector of activity, location, etc.—and data on their economic performance (sales, profits, employees, etc.). As for the data on TTOs and their TT activity we relied on information collected through an annual survey of TTOs in Italian universities carried out by Netval. The survey collects data on age, size (in terms of staff members and budget) and total expenditures of the TTOs. The survey also collects information on the technology transfer activities of universities: patents owned, new patent grants, amount of collaborative research, involvement in technology parks and incubators, etc.

Table 1 shows the 37 institutions that applied for the UIBM action and therefore used the economic incentives; they employed 75 additional professionals in their TTOs.[5] The first "new" employees started to work in January 2016 and the last ones in October 2017. Considering that the latest available information on TTO performance regards 2017, the analysis was restricted to those employees who had been working since 2016 (i.e. 48 people) to ensure a proper time delay and cause-effect relationship (Table 2).

Our sample includes information from both those universities which are UIBM-action beneficiaries and those which are not. Universities not recorded in the Netval survey or with a large amount of missing data have been excluded from the analysis. Our final sample therefore contains 24 Italian universities that benefitted from the UIBM action in 2016 and 36 that did not.

[4] Netval is the Italia association of universities for technology transfer: www.netval.it.

[5] All projects were accepted by UIBM in the first (2015–2017) call. The call was confirmed for a second time (2018–2020) and will most probably be confirmed for a third time (2020–2022).

Table 1 Organizations (universities and other public research centres) which were beneficiaries of the UIBM-MISE Action and number of additional TTO staff in the whole first call (2016 and 2017) and starting work in 2016

Organization	Additional TTO staff starting work in 2016 and 2017	Additional TTO staff starting work in 2016
Centro di riferimento oncologico	1	1
Istituto Nazionale di Astrofisica	1	–
Istituto Nazionale di Fisica Nucleare	1	–
Politecnico delle Marche (*)	3	3
Politecnico di Milano (*)	3	3
Politecnico di Torino (*)	3	3
Scuola Intern. Superiore di Studi avanzati di Trieste (*)	1	1
Scuola Superiore Sant'Anna di Pisa (*)	2	2
Università "Ca' Foscari" di Venezia (*)	3	3
Università Campus Bio-Medico di Roma	1	–
Università degli Studi di Napoli Federico II (*)	3	3
Università del Sannio (*)	1	1
Università della Calabria	2	–
Università dell'Aquila (*)	3	3
Università di Bari (*)	2	2
Università di Bologna (*)	3	2
Università di Brescia (*)	1	1
Università di Cagliari	3	–
Università di Camerino	2	–
Università di Ferrara	3	–
Università di Firenze (*)	2	1
Università di Messina (*)	2	2
Università di Milano "Bicocca" (*)	3	3
Università di Modena e Reggio Emilia (*)	1	1
Università di Palermo	3	–
Università di Pisa (*)	2	2
Università di Salerno	2	–
Università di Siena	2	–
Università di Torino (*)	1	1
Università di Trento (*)	2	1
Università di Trieste (*)	3	1
Università di Udine (*)	3	3
Università di Urbino Carlo Bo (*)	1	1
Università di Verona	2	–
Università IUAV di Venezia (*)	1	1
Università Mediterranea di Reggio Calabria	2	2
Università Tor Vergata di Roma (*)	1	1
Total	75	48

(*) Universities that belong to the final sample as beneficiaries of the UIBM-MISE Action in 2016

Table 2 Universities included in the final sample for our study

Non beneficiaries of the UIBM-MISE Action in 2016	Beneficiaries of the UIBM-MISE Action in 2016
Libera Università di Bolzano	Politecnica delle Marche
Politecnico di Bari	Politecnico di Milano
Scuola IMT Alti Studi Lucca	Politecnico di Torino
Scuola Normale Superiore di Pisa	Scuola Intern. Superiore di Studi avanzati di Trieste
Seconda Università di Napoli	Scuola Superiore Sant'Anna di Pisa
Telematica G. Marconi	Università "Ca' Foscari" di Venezia
Università Campus Bio-Medico di Roma	Università degli Studi di Napoli Federico II
Università degli Studi della Tuscia	Università del Sannio
Università degli Studi dell'Insubria	Università dell'Aquila
Università del "Piemonte Orientale"	Università di Bari
Università del Molise	Università di Bologna
Università del Salento	Università di Brescia
Università della Basilicata	Università di Firenze
Università della Calabria	Università di Messina
Università della Valle D'Aosta	Università di Milano "Bicocca"
Università di Bergamo	Università di Modena e Reggio
Università di Cagliari	Università di Pisa
Università di Camerino	Università di Torino
Università di Catania	Università di Trento
Università di Chieti-Pescara	Università di Trieste
Università di Ferrara	Università di Udine
Università di Foggia	Università di Urbino
Università di Genova	Università IUAV di Venezia
Università di Macerata	Università Tor Vergata di Roma
Università di Milano	
Università di Padova	
Università di Palermo	
Università di Parma	
Università di Pavia	
Università di Perugia	
Università di Salerno	
Università di Sassari	
Università di Siena	
Università di Teramo	
Università di Verona	
Università Magna Grecia di Catanzaro	

Table 3 shows that the two groups had very similar characteristics in 2016. This means that their situation (in terms of size, TTO age, etc.) at the time the action was launched did not have an influence on their decision to apply or not for the action itself. The Ttest of mean difference reported in Table 3 shows that there were no statistically significant differences in age and size of TTOs between the beneficiary and

Table 3 Sample descriptive of TTOs (both UIBM beneficiaries and not in 2016)

Beneficiaries of the UIBM-MISE Action	N (%)	TTO age in years Mean (St. Err.)	TTO size (n. people) before the UIBM-MISE Action Mean (St. Err.)	TTO size (n. people) after the UIBM-MISE Action Mean (St. Err.)	TTO productivity Mean (St. Err.)
No	36 (60)	10.31 (0.79)	3.37 (0.38)	3.37 (0.38)	1.58(0.29)
Yes	24 (40)	11.25 (0.79)	3.47 (0.60)	5.34 (0.63)	4.09 (1.25)
Ttest of mean diff		−0.8066			−2.2554
Total	60 (100)	10.69 (0.57)	3.41 (0.33)	4.24 (0.37)	2.6 (0.59)

non-beneficiary universities. This ensures that the age and initial size of the TTO can be considered as exogenous variables.

Indeed, we consider the size of TTOs before the action and the age of TTOs as control variables.

Rogers et al. (2000) find a positive correlation between the age of TTOs and their performance. Also Carlsson and Fridh (2002), find that the age of TTOs has a positive impact on university patenting and licensing. Research indicates that the TTO's experience is a critical determinant of a university's patenting capacity (Baldini et al. 2005; Owen-Smith and Powell 2001). Friedman and Silderman (2003) also found that universities with more experienced TTOs, measured by age, generate more licenses and license income. Debackere and Veugelers (2005, p. 339) note that TTOs learn 'how to optimize the various transfer mechanisms and monitoring processes through experimentation'. Similarly, Mowery et al. (2002), after examining changes in commercialization performance, argue that TTOs learn about patenting by doing it. However, contrary to the above-mentioned evidence, Ustundag et al. (2011) find that older TTOs are not necessarily more efficient. This may highlight the possibility that older TTOs are staffed by people with administrative/bureaucratic competence rather than with a managerial background and may suggest a need to recruit expertise from the private sector (Chapple et al. 2005). Caldera and Debande (2010) find that the age and specialization of the TTO do not affect spin-off activity and Chapple et al. (2005) indicate that older TTOs are not necessarily more efficient, due to the fact that they can be composed of people who have acquired a bureaucratic orientation rather than managerial and IP-specific competencies. Also, Muscio (2010), for the Italian context, finds that longer established TTOs appear to have the same level of efficiency as newer ones, suggesting the absence of learning effects.

Taking into account the controversial findings in the literature and also considering the fact that Italian TTOs are fairly recent and have employed rather young staff in the last few years, our expectation concerning the age of a TTO is that it will have a positive effect on the performance in TT in terms of licences and ASOs.

Siegel et al. (2003) consider invention disclosures to be the most important measurable input for the TTO, due to the fact that they represent the stock of transferable technology and new ideas. In this paper we chose to analyze the performance and effectiveness of TTOs using the following dependent variables: number of identified inventions, number of new spin-off companies, number of licenses and license revenues.

We do not consider in our analysis the number of patents granted, due to the fact that new people were active in the TTOs in 2016 and 2017 and the latest output data regard 2017. In this sense, no impact on patents granted in 2017 is possible, since the administrative procedures to obtain the grant of a patent started before the entrance of the new employees.

With regard to our case study, Italy is a large European country with a relevant manufacturing presence and the need to increase the innovative/technological component of its industrial structure (Grimaldi et al. 2020). The productivity of its scientific system is good, despite the lower number of researchers in comparison with similar countries. In such a situation it is not surprising that the importance of the university third mission has been intensively growing in recent years (Bax et al. 2014; Cesaroni and Piccaluga 2005), and within such a mission, technology transfer from university to industry has also obtained growing interest among both academics and policy makers. As a consequence, most Italian universities set up their TTOs during the last decade. Nonetheless, if we compare the Italian, European and US situations, it emerges that Italian TTOs are much smaller than TTOs set up in other European countries and in the US (Cesaroni and Piccaluga 2015) and that despite a number of relevant positive changes, there is room for improvement in the Italian TT system (OECD/EU 2019).

On the basis of the hypothesis that TTO size does matter in terms of performance, in order to assess the existence of differences in the performances of the TTOs which have been beneficiaries of the UIBM action and those which have not, we computed two types of growth rates of the principal outcome variables:

- the growth rates of each performance variable between 2015 and 2016 and between 2016 and 2017, denoted by g^1 (y/y − 1);
- the growth rates of each performance variable computed as the ratio between the value in 2016 and the average value of 2013–2014–2015 and computed as the ratio between the value in 2017 and the average value of 2014–2015–2016, denoted by g^2 (y/y − 1, y − 2, y − 3).

Results of tests on growth rates of performance variables by year are shown in Table 4. The data show that for the years 2016 and 2017 the difference in the growth rate is statistically significant in favor of beneficiaries of the UIBM-MISE action if we consider the number of identified inventions, licenses and licenses revenues.

4 Methodology

To test our research hypotheses, we estimated several panel regression models. Panel regression methods are widely applied in econometric analysis, allowing to pool multidimensional information observed across units (e.g. universities) and through time (e.g. years) to better explain within- and between-variability in the data set. There are some key benefits for the adoption of the panel regression approach, including the specification of a regression framework wherein all data across universities and through time can be considered simultaneously; a tool to handle unobservable heterogeneity between universities, and the ability to examine time series trends through universities concurrently. Panel regression techniques are therefore considered appropriate to make fuller use of information contained in multidimensional data sets (Wooldridge 2010).

In particular, we estimated several models of panel linear and Poisson (according to the type of dependent variable) GEE population-averaged regression, each specifically tailored for the four hypotheses. We used panel data models to take into account university-specific heterogeneity and because such data are particularly suitable for studying the dynamics of change (Cameron and Trivedi 2009).

In our panel models, the dependent variable varies according to each studied performance variable (number of identified inventions, number of licenses, revenues from licenses and number of new spin-offs) and the couple university-year represents the unit of observation. Moreover, universities have been classified according to the quartiles of the distribution of the dimensions of TTOs (without considering the increase in staff due to the UIBM action). We also controlled for years.

In addition, we created interaction-terms to capture specific effects related to the UIBM-Action. The first group is given by the interactions between the size (small, medium or big) and the number of additional TTO staff: the associated regression coefficients are useful for assessing whether the effect of the policy is greater for small, medium or large universities. The second group is given by the interactions between the quartiles of the distribution

Table 4 Tests on growth rates of performance variables

Performance variable	Growth rates year 2016				Growth rates year 2017		
	Growth rate type	UIBM-MISE Action beneficiaries in 2016 Mean (St. Err.)	No UIBM-MISE Action beneficiaries in 2016 Mean (St. Err.)	*P* value (*)	UIBM-MISE Action beneficiaries in 2016 Mean (St. Err.)	No UIBM-MISE Action beneficiaries in 2016 Mean (St. Err.)	*P* value (*)
Number of identified inventions	g^1(y/y – 1)	+ 23.5% (11.81)	+ 1.0% (9.44)	0.065*	+ 464.0% (233.9)	+ 66.1% (62.6)	0.051*
	g^2(y/y – 1,y – 2,y – 3)	+ 20.2% (8.45)	+ 0.3% (7.43)	0.038**	+ 607.3% (256.9)	– 5.7% (20.7)	0.006**
Number of licenses	g^1(y/y – 1)	+ 35.0% (12.55)	+ 12.6% (10.12)	0.084*	+ 57.7% (37.5)	– 77.9% (11.3)	0.003**
	g^2(y/y – 1,y – 2,y – 3)	+ 30.0% (11.10)	+ 11.1% (8.26)	0.086*	+ 115.1% (69.8)	– 9.4% (48.0)	0.075*
License revenues	g^1(y/y – 1)	+ 25.5% (18.55)	– 5.0% (12.53)	0.082*	NA	NA	
	g^2(y/y – 1,y – 2,y – 3)	+ 25.2% (16.35)	– 1.6% (11.92)	0.091*	– 74.4% (22.1)	+ 48.8% (120.0)	0.880
Number of spin-offs	g^1(y/y – 1)	– 14.0% (12.12)	+ 3.9% (13.55)	0.825	+ 37.2% (48.2)	+ 43.4% (36.5)	0.541
	g^2(y/y – 1,y – 2,y – 3)	– 21.1% (10.70)	– 18.2% (10.56)	0.575	+ 69.5% (59.6)	+ 26.6% (37.6)	0.263

(*) Hp.: Mean (UIBM-Action = Yes) > Mean (UIBM-Action = No) of the dimension of TTOs described above and the number of additional TTO staff: the associated regression coefficients are useful for assessing whether the effect of the policy is greater for small, medium-small, medium-large and large previous dimension of TTOs.

5 Results

If we consider the number of identified inventions (Table 5), having more people in the TTOs has a positive and statistically significant effect; the same occurs for the age of the TTO. The effect of additional TTO employees is positive and significant for small, medium and large universities. The effect is positive, significant and similar for + 1, + 2 and + 3 additional units in the TTOs; however, the intensity of the effect is stronger in the + 3 case. Moreover, the effects of additional employees are positive and significant for TTOs belonging to all quartiles of the distribution of TTO size, with a higher impact for the third and fourth quartiles, that include the largest universities.

Concerning the number of licenses (Table 6), having more people in the TTOs does not seem to affect this specific aspect of performance in general terms, while the age of the TTOs has a positive and significant effect. However, the effect of additional staff is positive and significant only for the TTOs belonging to the second and third quartile (small-medium and medium-large previous size of TTOs).

Regarding revenues from licenses (Table 7), having more people in the TTOs does not affect performance in the short term (the effect is generally positive but not significant). In this case, TTO age shows a negative but not significant effect. However, the effect of additional staff is positive and significant for large universities, for + 3 additional TTO units and for TTOs belonging to the first, third and fourth quartile (small, medium-large and large previous dimension of TTOs).

Considering the number of new spin-offs (Table 8), having more people in the TTOs does not affect performance in general terms, whereas the effect of the age of the TTO is positive and significant. Positive and significant effects of additional TTO employees only appear for small universities and when the TTO grows by three units.

Table 9 reports a summary of the hypothesis confirmed or not.

6 Discussion

The size of TTOs in Italian universities remained fairly stable in the period 2011–2015 ranging between 3 and 4 employees. After the UIBM measure the average increased significantly. This increase occurred in the universities that applied for the measure: in 2017 the average for this group was 6.2 employees.

The results of the empirical analysis show that adding staff in the TTOs has a very clear and positive effect on the identification of inventions. In fact, as expected, having more people in the TTOs allows for more contacts and interactions with researchers, since TT staff can visit the labs, organize meetings with researchers, call them frequently, etc. It is like looking for mushrooms: the mushrooms are out there in the woods: more people correspond to more eyes and therefore more mushrooms collected.

Hp1 is confirmed. The fact that the majority of Human Resources employed with the action have a PhD can explain the difference with the results of Hulsbeck et al. (2013, p. 210) that motivate the negative results for German universities by asserting that "the rather

Table 5 Poisson panel regressions, GEE population-averaged models (number of identified inventions)

Poisson panel regressions, GEE population-averaged models	Mod. 1		Mod. 2		Mod. 3		Mod. 4	
Outcome = Number of identified inventions	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value
TTO staff (etp) total	0.02	0.006**						
TTO staff (etp) without additional UIBM staff			−0.03	0.000***	0.03	0.000***	−0.03	0.000***
Age TTO	0.11	0.000***	0.14	0.000***	0.14	0.000***	0.14	0.000***
Small university	0.19	0.397	−0.09	0.705	−0.02	0.940	0.08	0.716
Medium university	−0.10	0.500	−0.30	0.062*	−0.46	0.004**	−0.31	0.053*
Big university	1.07	0.000***	0.78	0.000***	0.83	0.000***	0.84	0.000***
Small university * num. additional TTO staff (UIBM)			0.24	0.004**				
Medium university * num. additional TTO staff (UIBM)			0.12	0.001**				
Big university * num. additional TTO staff (UIBM)			0.25	0.000***				
TTO additional staff = 1 (ref. category = 0)					0.15	0.004**		
TTO additional staff = 2 (ref. category = 0)					0.37	0.000***		
TTO additional staff = 3 (ref. category = 0)					0.70	0.000***		
1st quartile TTO staff without additional UIBM staff * num. add. TTO staff (UIBM)							0.22	0.000***
2nd quartile TTO staff without additional UIBM staff * num. add. TTO staff (UIBM)							0.11	0.006**
3rd quartile TTO staff without additional UIBM staff * num. add. TTO staff (UIBM)							0.25	0.000***
4th quartile TTO staff without additional UIBM staff * num. add. TTO staff (UIBM)							0.25	0.000***
Year 2012	−0.08	0.031**	−0.07	0.064*	−0.07	0.062**	−0.07	0.065*
Year 2013	0.13	0.001**	0.12	0.001**	0.12	0.001**	0.12	0.001**
Year 2014	−0.06	0.100	−0.05	0.150	−0.05	0.152	−0.05	0.158
Year 2015	0.25	0.000***	0.28	0.000***	0.28	0.000***	0.28	0.000***
Year 2016	0.32	0.000***	−0.002	0.957	0.03	0.524	0.01	0.733
Year 2017	0.41	0.000***	0.12	0.002**	0.15	0.000***	0.13	0.001**
Model goodness of fit								
Number of observations	357		357		357		357	
Number of groups	58		58		58		58	

Table 5 (continued)

Poisson panel regressions, GEE population-averaged models	Mod. 1		Mod. 2		Mod. 3		Mod. 4	
Outcome = Number of identified inventions	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value
Wald Chi2	8061.17		9027.97		8984.41		9031.62	
Prob. > Chi2	0.000		0.000		0.000		0.000	

Table 6 Poisson panel regressions, GEE population-averaged models (number of licenses)

Poisson panel regressions, GEE population-averaged models outcome = Number of licenses	Mod. 1		Mod. 2		Mod. 3		Mod. 4	
	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value
TTO staff (etp) total	0.03	0.059*						
TTO staff (etp) without additional UIBM staff			−0.02	0.948	−0.03	0.246	−0.01	0.753
Age TTO	0.07	0.005**	0.10	0.000***	0.10	0.000***	0.10	0.000***
Small university	−1.47	0.010**	−1.43	0.014**	−1.44	0.011**	−1.58	0.007**
Medium university	−1.63	0.000***	−1.86	0.000***	−1.81	0.000***	−1.77	0.000***
Big university	−0.45	0.209	−0.57	0.128	−0.57	0.119	−0.70	0.067*
Small university* num. additional TTO staff (UIBM)			0.20	0.417				
Medium university* num. additional TTO staff (UIBM)			0.40	0.000***				
Big university* num. additional TTO staff (UIBM)			0.32	0.000***				
TTO additional staff = 1 (ref. category = 0)					0.07	0.665		
TTO additional staff = 2 (ref. category = 0)					0.28	0.186		
TTO additional staff = 3 (ref. category = 0)					0.99	0.000***		
1st quartile TTO staff without additional UIBM staff* num. add. TTO staff (UIBM)							0.30	0.000
2nd quartile TTO staff without additional UIBM staff* num. add. TTO staff (UIBM)							0.27	0.030***
3rd quartile TTO staff without additional UIBM staff* num. add. TTO staff (UIBM)							0.46	0.000***
4th quartile TTO staff without additional UIBM staff* num. add. TTO staff (UIBM)							0.30	0.000
Year 2012	−0.11	0.379	−0.09	0.460	−0.09	0.451	−0.09	0.429
Year 2013	0.09	0.471	0.10	0.390	0.09	0.386	0.09	0.398
Year 2014	−0.06	0.641	−0.05	0.687	−0.05	0.691	−0.05	0.647
Year 2015	0.26	0.023**	0.28	0.010**	0.28	0.008**	0.27	0.011**
Year 2016	0.37	0.002**	−0.08	0.531	−0.02	0.882	−0.12	0.329
Year 2017	0.39	0.002**	0.03	0.807	0.12	0.385	0.01	0.944
Model goodness of fit								
Number of observations	324		324		324		324	
Number of groups	57		57		57		57	

Table 6 (continued)

Poisson panel regressions, GEE population-averaged models outcome = Number of licenses	Mod. 1		Mod. 2		Mod. 3		Mod. 4	
	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value
Wald Chi2	202.01		298.96		332.94		351.10	
Prob. > Chi2	0.000		0.000		0.000		0.000	

Table 7 Linear panel regressions, GEE population-averaged models (license revenues)

Linear panel regressions, GEE population-averaged models	Mod. 1		Mod. 2		Mod. 3		Mod. 4	
Outcome = License revenues	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value
TTO staff (etp) total	813.4	0.205						
TTO staff (etp) without additional UIBM staff			−190.5	0.764	72.6	0.912	119.5	0.858
Age TTO	−163.9	0.712	28.8	0.945	−75	0.863	−45.3	0.916
Small university	538.6	0.943	1782	0.806	2060.2	0.781	1272.6	0.862
Medium university	1993.3	0.728	4434.3	0.415	3156.3	0.572	3003.4	0.590
Big university	11,243.9	0.108	11,624.4	0.079*	13,119.7	0.054	12,281.5	0.070*
Small university * num. additional TTO staff (UIBM)			3188.3	0.662				
Medium university * num. additional TTO staff (UIBM)			1162.4	0.702				
Big university * num. additional TTO staff (UIBM)			13,446.6	0.000***				
TTO additional staff = 1 (ref. category = 0)					1320.5	0.833		
TTO additional staff = 2 (ref. category = 0)					4563	0.607		
TTO additional staff = 3 (ref. category = 0)					29,340.3	0.000***		
1st quartile TTO staff without additional UIBM staff * num. add. TTO staff (UIBM)							9445	0.002**
2nd quartile TTO staff without additional UIBM staff * num. add. TTO staff (UIBM)							4864.8	0.253
3rd quartile TTO staff without additional UIBM staff * num. add. TTO staff (UIBM)							11,372.9	0.004**
4th quartile TTO staff without additional UIBM staff * num. add. TTO staff (UIBM)							8312.2	0.011**
Year 2012	−1879.2	0.672	−1537.9	0.718	−1596.4	0.710	−1545.8	0.721
Year 2013	−1118.9	0.799	−808.7	0.847	−833.2	0.844	−819.1	0.848
Year 2014	−5139.8	0.239	−4978.7	0.234	−4985.7	0.238	−4939.7	0.246
Year 2015	52.2	0.990	520.7	0.899	389	0.925	437	0.917
Year 2016	5855.8	0.192	−1576.7	0.736	584.8	0.905	−1656.1	0.729
Year 2017	2224.5	0.642	−3429.2	0.480	−2417.7	0.631	−4269.5	0.387
Model goodness of fit								
Number of observations	312		312		312		312	
Number of groups	56		56		56		56	

Table 7 (continued)

Linear panel regressions, GEE population-averaged models	Mod. 1		Mod. 2		Mod. 3		Mod. 4	
Outcome = License revenues	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value
Wald Chi2	44.29		79.16		66.56		65.10	
Prob. > Chi2	0.000		0.000		0.000		0.000	

Table 8 Poisson panel regressions, GEE population-averaged models (number of new spin-off)

Poisson panel regressions, GEE population-averaged models	Mod. 1		Mod. 2		Mod. 3		Mod. 4	
Outcome = Number of new spin-off	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value
TTO staff (etp) total	0.01	0.679						
TTO staff (etp) without additional UIBM staff			0.01	0.753	0.005	0.845	0.01	0.800
Age TTO	0.06	0.002**	0.06	0.001**	0.06	0.001**	0.06	0.001**
Small university	−0.26	0.715	−0.35	0.640	−0.25	0.724	−0.26	0.713
Medium university	−0.53	0.032	−0.53	0.030**	−0.52	0.032**	−0.52	0.038**
Big university	0.03	0.925	0.04	0.881	0.03	0.906	0.04	0.889
Small university* num. additional TTO staff (UIBM)			0.28	0.089*				
Medium university* num. additional TTO staff (UIBM)			0.10	0.126				
Big university* num. additional TTO staff (UIBM)			0.03	0.742				
TTO additional staff = 1 (ref. category = 0)					−0.09	0.640		
TTO additional staff = 2 (ref. category = 0)					0.01	0.978		
TTO additional staff = 3 (ref. category = 0)					0.19	0.350***		
1st quartile TTO staff without additional UIBM staff* num. add. TTO staff (UIBM)							0.0005	0.997
2nd quartile TTO staff without additional UIBM staff* num. add. TTO staff (UIBM)							0.09	0.370
3rd quartile TTO staff without additional UIBM staff * num. add. TTO staff (UIBM)							0.12	0.413
4th quartile TTO staff without additional UIBM staff* num. add. TTO staff (UIBM)							0.04	0.445
Year 2012	0.21	0.243	0.21	0.243	0.21	0.242	0.21	0.242
Year 2013	0.05	0.783	0.05	0.784	0.05	0.782	0.05	0.782
Year 2014	0.26	0.164	0.26	0.166	0.26	0.163	0.26	0.164
Year 2015	0.14	0.427	0.15	0.431	0.15	0.420	0.15	0.425
Year 2016	−0.03	0.883	−0.09	0.695	−0.05	0.838	−0.09	0.685
Year 2017	−0.05	0.788	−0.10	0.600	−0.06	0.753	−0.09	0.638
Model goodness of fit								
Number of observations	350		350		350		350	
Number of groups	56		56		56		56	

Table 8 (continued)

Poisson panel regressions, GEE population-averaged models	Mod. 1		Mod. 2		Mod. 3		Mod. 4	
Outcome = Number of new spin-off	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value	Coeff	*P* value
Wald Chi2	316.19		328.38		320.60		323.73	
Prob. > Chi2	0.000		0.000		0.000		0.000	

Table 9 Identification of Hypothesis confirmed (✓ = confirmed, ✗ = not confirmed)

Panel model	Effect of additional TTO staff	Number of identified inventions	Number of licenses	License revenues	Number of new spin-offs
		Hp1 Positive effect	Hp2 Positive effect	Hp3 No effect	Hp4 Positive effect
Model 2	Small universities	✓	✗	✓	✓
	Medium universities	✓	✓	✓	✗
	Big universities	✓	✓	✗	✗
Model 3	TTO + 1 unit	✓	✗	✓	✗
	TTO + 2 units	✓	✗	✓	✗
	TTO + 3 units	✓	✓	✗	✓
Model 4	Small TTOs	✓	✗	✗	✗
	Small-medium TTOs	✓	✓	✓	✗
	Medium-large TTOs	✓	✓	✗	✗
	Large TTOs	✓	✗	✗	✗

low percentage of employees with a PhD reveals that TTOs in Germany are more a subdivision of the administration then a unit concerned with bringing ideas to the market. Only about 17% percent of the employees own a doctoral degree. A necessary condition for the UITT is that members of the TTO are appropriate and adequate counterparts of the scientists. This might not be the case in general in Germany".

In the case of a new action, the attention to select new employees with high human capital may have contributed to fact that increasing the size of TTOs has had a positive effect on the number of invention disclosures.

The positive effect on licenses and revenues that we found was beyond our expectations and so, after the tests on the growth rates of performance variables (Table 4), we run regressions in order to be sure that the results were robust and not influenced by other factors, even if the two starting groups (UIBM action beneficiaries and no beneficiaries) were quite similar in terms of size and age (Table 3). To better understand the impact of such an action, we ran the regressions for the whole set of TTO performance variables available in Netval: inventions, licenses and revenues and new spin-offs. After this check (Table 9), we found that the positive effect is still robust for medium-small TTOs for licenses (2nd and 3rd quartiles of the distribution of the dimensions of TTOs) and for small, medium-large and large TTOs for revenues (1st, 3rd and 4th quartiles of the distribution of the dimensions of TTOs). Therefore, in terms of licenses, this means that universities with small-medium TTOs have been the "woods" where there were more additional "mushrooms" to be collected and where having more people working in the TTOs was particularly useful. Universities with small-medium TTOs are probably younger in the job, less expert and they really needed new people to be involved in a relatively codified task such as invention disclosure.

As a matter of fact, the effect on the number of licenses is not significant in accordance with other authors who analyze European universities (Chapple et al. 2005; Goldfarb and Henrekson 2003; Krücken et al. 2007; Muscio 2010; Saragossi and van Pottelsberghe de la Potterie 2003; Sellenthin 2009; Van Looy et al. 2011; Siegel et al. 2003; Lach and Schankerman 2004). However, there are some positive (and significant) effects for medium-sized and big universities, probably because the identification of more inventions is something that characterizes smaller TTOs, whereas licensing (and revenues) is something more typical of medium sized TTOs. In these TTOs, most probably, there was already some interesting IP and maybe some potential contacts with licensees. As a consequence, the involvement of new staff has allowed to achieve the results which had, in some way, been prepared by those who had worked before them. This is not the case in larger TTOs, where new staff has been probably directed towards longer term activities and whose fruits will be collected in the future.

Concerning Hp4, it is confirmed only for small universities and for an increase of three units in TTO.

Starting from the evidence of the empirical model, we try to identify an optimal size of the TTO. This would depend on the overall size of the university and, most of all, on the technology transfer propensity of its departments. We can hypothesize that the universities that applied for the UIBM measures were those with a TTO size below what they considered as optimal and they took advantage of this change to enlarge it. On the contrary, those that did not apply for the UIBM measure had no interest to enlarge the TTO as it already was the optimal size (or was even larger than the optimal).[6]

[6] The UIBM measure requested universities to co-finance the new employees. This means that there could be universities that were willing to apply but had to renounce due to financial constraint. We are not able to

Table 10 Disclosures per employee in universities that did not apply for the UIBM measure (0) and those that applied (1)

Year	No UIBM-MISE Action beneficiaries in 2016	UIBM-MISE Action beneficiaries in 2016	Total
2011	1.5	3.7	2.5
2012	1.6	2.4	1.9
2013	2.1	3.0	2.5
2014	1.7	2.3	2.0
2015	1.6	4.1	2.6
2016	2.0	3.6	2.7
2017	1.7	4.1	2.7

One of the best indicators for analyzing the optimal size of a TTO is to look at the productivity of its employees. We constructed a simple proxy of TTO productivity by considering the number of invention disclosures per employee. Invention disclosures are the first step in the technology transfer process on which the other activities (such as patent application or spin-off set-up) will be based.[7]

The average number of invention disclosures per employee in the period 2011–1015 (before the UIBM measure) was about 2.5. However, the distribution per universities is even more skewed than that of employees, with a significant number of universities having values below the average. This suggests that in some universities the TTO was set-up on the basis of the 'must have' principle, although they must still express their potential.

The two groups of universities (those that applied for the UIBM measure and those that did not) show no significant differences in terms of size and age of the TTO in the years before the application.

However, if we consider the productivity of employees there is a significant difference between the two groups: those that applied for the UIBM measure show a higher productivity, more than double the one observed in universities that did not apply (Table 3).

This confirms the hypothesis previously mentioned about the decision of universities to take advantage of the UIBM measure. Those universities with a low productivity had no incentive to further enlarge the number of employees. They were in some respect 'over staffed'; their main preoccupation was to increase the output of those already occupied in the TTO (whose productivity was below average).

The universities with a high level of employee productivity had the potential to increase the output of their TTO by further enlarging it. This expectation was fulfilled: they significantly increased the number of disclosures in 2016 and 2017. This means that the universities that applied for the UIBM measure were 'understaffed' and took advantage of the UIBM-MISE measure to reach the optimal size for their TTO.

This is further confirmed by considering that the average productivity per employee did not diminish after the recruitment of additional people through the UIBM measure (Table 10).

Footnote 6 (continued)

know whether or not there were such cases. Overall, this is not expected to influence the general result of the analysis.

[7] We also considered an overall measure of productivity by considering the sum of innovation disclosures, patent applications and spin-offs, obtaining the same results.

As mentioned before, the UIBM measure gave the possibility to hire 1, 2 or 3 new employees. We expect that the choice of the additional number of employees was based on what the universities considered the optimal size of their TTO. A way of verifying this aspect is to look at the productivity of employees before and after the enlargement of the TTO, by splitting universities according to the number of new employees (Table 11).

The universities that recruited 1 or 2 employees slightly increased their productivity, which remained within their long-term level. This suggests that the choice of recruiting 1 or 2 additional employees was based on what they thought was the optimal size of their TTO (or the optimal rate of its enlargement). In the case of the universities that hired 3 new staff the productivity significantly increased over the long-term level, following a growing trend. The absolute level of employee productivity is much higher than the average, suggesting that these universities had not yet reached the optimal size of their TTO and would be willing to hire further additional staff (3 was the maximum number allowed by the UIBM measure).

7 Conclusion

Our results show that adding more people to the TTOs had a very clear effect on the one variable which can be realistically influenced in the short term, i.e. invention disclosures. Having more people in the TTOs meant they had more opportunities of creating contacts with researchers and therefore determining an increase in the number of invention disclosures within a relatively short period of time. The same positive effect generally emerges also for other TTO performance variables such as the number of licenses and license revenues. On the other hand, we observe less impact on the number of new-spinoffs.

We need to emphasize that this effect was produced in less than two years, considering that new people were—on average—involved in the TTOs in the first term of 2016 and outcomes refer to 2017.

The use of lagged TTO outcomes allowed us to detect a significant increase also in output variables, even if they would normally require a period longer than a few months in order to be observed. In other words, we can argue that having more people in TTOs does determine an increase in the number of patent applications, and in the licenses/revenues, especially when the TTO grows by 3 units.

The universities that took advantage of the UIMB measure were those with a high level of employee productivity and had the potential to increase the output of their TTO by further enlarging it. Indeed, they significantly increased the number of disclosures in 2016 and 2017. This means that the universities that applied for the UIBM measure were 'understaffed' and took advantage of the UIBM measure to reach the optimal size for their TTO.

The first UIBM action brought new people to a number of Italian TTOs in 2016 and we analyzed data from 2012 to 2017. However, the UIBM action was renewed in 2018. As a result, most previous beneficiaries had the opportunity of confirming their "new" staff and other new beneficiaries were included. It will thus be interesting to use output data from 2018 to verify the robustness of the achieved results in the long term. Moreover, with new 2018 data, it will be possible to observe if results about invention disclosures will be confirmed, i.e. if there will be an additional growth or if most of the potential was collected in the first 2 years.

In general, the fact that we observed a positive impact from the involvement of new people in the TTOs even in a short period of less than two years leads us to argue that the

Table 11 Disclosures per employee in universities that did not apply for the UIBM measure (0) and those that applied according to the number of new staff

Year	No UIBM-MISE Action beneficiaries in 2016	UIBM-MISE Action beneficiaries in 2016 (+1 unit)	UIBM-MISE Action beneficiaries in 2016 (+2 units)	UIBM-MISE Action beneficiaries in 2016 (+3 units)	Total
2011	1.5	4.7	3.0	3.0	2.5
2012	1.6	2.3	1.9	2.8	1.9
2013	2.1	2.1	3.0	4.3	2.5
2014	1.7	2.1	1.3	3.2	2.0
2015	1.6	1.7	2.0	8.4	2.6
2016	2.0	2.1	2.1	6.3	2.7
2017	1.7	3.3	2.8	5.5	2.7

impact may reveal to be even stronger after a longer period, considering both the fact that the people will increase their professional competence and the fact that results in the field of valorization of research results usually need several years of work.

According to Barra and Zotti (2018), TTOs contribute significantly to technology transfer reducing the gap between academic research and business needs, and fostering the innovation process. This calls for a greater specialization of TTOs, an increase in their number of staff and in their employees' technology skills and competence.

From a practical point of view, we find that universities which were beneficiaries of the UIBM-MISE Action had not yet reached the optimal size of their TTO so they can add more people if they want to improve the productivity in their work.

In our analysis we do not consider the number of patents granted. Since new people were active in the TTOs in 2016 and 2017 and the latest output data regard 2017, no impact on patents granted in 2017 is possible, since patents granted in 2017 are the result of administrative procedures which began before the entrance of the new employees. Patenting activity, also for technical reasons, is the result of medium-term efforts and procedures and the presence of new TTO staff cannot determine an increase in the number of patents granted in the short term. Since more inventions have been identified, it is however likely that—in the medium term—more patent applications will be made and more patents will be granted. For this reason, a future line of research should evaluate the impact of this action in the coming years on this further indicator of TTO performance.

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