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How institutional nature and available resources determine the performance of technology transfer offices

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ABSTRACT

This paper assesses the performance of GAPIs and OTICs, two different types of university technology transfer offices that have been active in Portuguese higher education institutions, since 2000 and 2006, respectively. Data originating from a survey of these offices were analysed through both cluster analysis and the estimation of a Partial Least Squares-Structural Equation Modelling (PLS-SEM) model. Results show that the institutional nature of each of the surveyed organisations implies different behaviours and outputs. Furthermore, it is shown that the resources and activities of the surveyed offices determine their performance concurrently with regard to technology transfer, licencing contracts and technology-based spin-offs. The results of this study may be particularly relevant for countries that are in the process of developing their university technology transfer activities, as they can help to shape policies in relation to TTOs' funding and resource allocation during the earlier stages of these activities.

KEYWORDS

Technology transfer; university–industry relationships; university patenting; university spin-offs

JEL CODES

O32: Management of Technological Innovation and R&D; O34: Intellectual Property Rights; I23: Higher Education and Research Institutions; L24: Contracting Out, Joint Ventures, Technology Licencing

1. Introduction

The purpose of this paper is to assess the performance of the two types of technology transfer offices (TTO) that have, respectively, been active in Portuguese universities and polytechnic institutes – GAPIs (Offices for the Promotion of Industrial Property), and OTICs (Technology and Knowledge Transfer Offices).

The dramatic growth of university patenting in Portugal follows on from the launching of GAPIs in 2000, during a first stage, and, during a second stage, the setting up of OTICs in 2006 (Table 1). During the first stage, the growth rates of demand for Portuguese patents, calculated by comparing the average figures for 2001–2005 with those of 2000, were, respectively, 35% for total national demand, and 148% for universities. During the second stage, from 2006 to 2010, as OTICs entered the scene, the growth rates were, respectively, 156% for total demand, and 317% for universities, these growth rates being measured by comparing the averages of both periods.

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Table 1. Patent applications and grants in Portugal, 2000–2015.

	Applications			Grants		
	Total	Universities	Ratio (%)	Total	Universities	Ratio (%)
2000	131	12	9	61	1	2
2001	159	23	14	56	5	9
2002	179	21	12	40	5	13
2003	175	24	14	142	23	16
2004	168	26	15	156	24	15
2005	206	55	27	208	39	19
2006	240	84	35	139	31	22
2007	314	108	34	182	68	37
2008	464	139	30	184	58	32
2009	665	169	25	180	73	41
2010	591	122	21	174	71	41
2011	660	138	21	144	41	28
2012	693	128	18	139	46	33
2013	742	140	19	162	45	28
2014	812	143	18	139	48	35
2015	1055	168	16	115	25	22

Source: For "applications" the source is inpi (www.marcasepatentes.pt), and for grants the source is Pordata (www.pordata.pt).

As can be seen, universities had a dramatic growth, up from just 12 applications in 2000, to yearly averages of 30 and 124 during the two subsequent periods. This compares with an evolution for the gross demand for national patents from 131 in 2000, to yearly averages of 177 and 455 during the two subsequent periods.

This evolution suggests that several factors may have played a role in the growth of both the national and university demand for patent protection. However, it is clear that the dynamic performance of universities during the periods under observation was much better than that of the national total. It is impossible to separate this performance from the inception of both GAPIs and OTICs during the two stages under observation. Furthermore, the relevance of the role of these structures is confirmed, as the performance of universities, which peaked at 169 applications in 2009, started to decrease slightly as public funding began drying up after the second stage. This evolution is particularly visible as the ratio of university patents applications to the gross national patent demand decreased continuously, from 35% in 2006, to just 16% in 2015. Even so, this still compares well with the equivalent rates of 4–5% for most of Europe and the U.S.

The figures for national patents granted in Portugal followed similar trends, with a small lag varying approximately between 2 and 4 years. As will be seen below, patenting is a pre-condition for (formal) university technology transfer (UTT), and it is thus important to analyse the activity of university TTOs in Portugal and their UTT performance.

The data used in this paper stem from a survey carried out at the request of the Technical University of Lisbon, referring to the period of 2006–2008. The survey focused on GAPIs and OTICs. In a few institutions, these two types of units have been merged into one, which means that we will be analysing three groups: the GAPI group, the OTIC group and a mixed GAPI + OTIC group (Table 2). The survey data have meanwhile been complemented by four qualitative case studies.

The specific objective of this paper was to research the determinants of the performance of the existing TTOs, and the resources and role of the institutional characteristics of the different types of structures that exist for university technology transfer in Portugal. We have already highlighted above the evolution of patenting, although other TTO outputs can also

be observed. We are interested in understanding how the TTOs performed in the sequence of a period of intense public funding, and which were the other pertinent factors, and also how the resources available in the Universities and the TTOs, together with the activities pursued, and universities' research output all affected their performance.

Given our research interest, this paper accordingly addresses two research questions. The first is whether the diversified institutional nature of the surveyed organisations implies different behaviours and outputs, and whether it is supported by the Institutional theory. The second is whether the resources and activities in the surveyed organisations and universities determine their outputs, namely technology transfer contracts, technology licencing contracts, technology-based spin-offs, and if this is supported by the Resource-Based View theory. We do not perceive these two theories as being diametrically opposed theoretical perspectives; however, we think that each of them brings different, possibly complementary, perspectives, which can be brought in as theoretical support for formulating each of the research questions.

The contribution of the paper to the literature is twofold. First, the results confirm that the institutional nature of each of the surveyed organisations actually implies different behaviours and outputs. Secondly, the results also show that the type of resources and activities available in the surveyed offices determines their performance.

This analysis might be meaningful for other medium and medium-high income economies that share similar specialisation patterns, notably in East and Central Europe, Latin America, and Asia.

Table 2. Surveyed entities.

Entity	Universities and polytechnics	Acronym
GAPI	Instituto Superior Técnico	GAPI IST
	Universidade dos Açores	GAPI Azores
	Universidade do Algarve	GAPI Algarve
	Universidade de Coimbra	GAPI Coimbra
	Universidade de Évora	GAPI Evora
	Universidade de Aveiro	GAPI Aveiro
	Universidade da Beira Interior	GAPI UBI
OTIC	Instituto Politécnico de Setúbal	OTIC IPS
	Instituto Politécnico de Tomar	OTIC IPT
	Instituto Politécnico do Porto	OTIC IPP
	Instituto Politécnico de Leiria	OTIC IPL
	Instituto Politécnico de Beja	OTIC IPBeja
	Instituto Politécnico de Castelo Branco	OTIC IPCB
	Instituto Politécnico de Portalegre	OTIC IPPg
	Instituto Politécnico de Viana do Castelo	OTIC IPVC
	Universidade Técnica de Lisboa	OTIC UTL
	U. Católica Portuguesa – Escola Superior de Biotecnologia	OTIC ESB
	Universidade do Algarve	OTIC Algarve
	Universidade da Beira Interior	OTIC UBI
	Universidade Nova de Lisboa	OTIC UNL
	Universidade de Coimbra	OTIC Coimbra
	Universidade Lusíada de Vila Nova de Famalicão	OTIC Lusíada
	Universidade de Aveiro	OTIC Aveiro
	Universidade de Évora	OTIC Evora
	Universidade de Lisboa	*No reply*
	Universidade da Madeira	*No reply*
Joint GAPI+OTIC	Universidade de Trás-os-Montes e Alto Douro	GAPI+OTIC UTAD
	Universidade do Porto	GAPI+OTIC Porto
	Universidade do Minho	GAPI+OTIC Minho

The paper is structured into six sections. Section 2 briefly surveys the literature on TTOs, and on the theories which lie behind each of the research questions, respectively, the Institutional Theory and the Resource-Based View (RBV). Section 3 elaborates on the nature and mission of the different types of TTOs in Portugal, with the help of the data extracted from four small case studies to illustrate their activities, and provides a brief comparison of their characteristics with similar organisations elsewhere. Section 4 identifies and elaborates on the research questions. Section 5 contains the empirical analysis, describing the quantitative survey and the variables of the study, presents the methodology, and describes the analysis of the results generated through cluster analysis and the estimation of a Partial-Least Squares model. Finally, Section 6 highlights the main conclusions and presents a few recommendations.

2. Literature review

We start the literature review by discussing the role of TTOs and the various steps of university technology transfer. After this we will turn to both the institutional and resource-based perspectives, which provide a theoretical background for analysing TTOs' performance.

2.1. The role of TTOs

During the UTT process, TTOs are active intermediaries between the management of universities, teachers and firms. They perform a systematic screening of existing knowledge within the universities and encourage researchers to both look for technological opportunities in their research, and also to disclose their findings.

According to Siegel et al. (2004), the main UTT steps are as follows: scientific discoveries in the university are disclosed to the TTO, which then evaluates their market potential and applies for a patent; after the patent is issued, the TTO markets the new technology to firms and finally issues a licence to an existing firm, or to a start-up (usually a spin-off from the university itself). Both Markman et al. (2005) and Bradley, Hayter, and Link (2013) call attention to the fact that this does not capture all the complexities of UTT in practice. Siegel, Waldman, and Link (2003) stress that sometimes the technology is licenced even before it is patented.

For Siegel, Veugelers, and Wright (2007), the role of a TTO is: to decide whether an invention should be patented; to assess its commercial value, and; to market it, seeking potential licensees and start-ups. For Macho-Stadler, Pérez-Castrillo, and Veugelers (2007) however, a TTO is a 'technology seller', which helps to reduce the asymmetric information problem. TTOs are instrumental in reducing the asymmetry of information between industry and science for the value of inventions, as neither are companies normally capable of assessing the quality of inventions ex-ante, nor are inventors experts in assessing the business value of their inventions, particularly when they arise from newer technologies (Markman et al. 2005). TTOs have been seen as having a comparative advantage in identifying potential partner firms for licencing university IP, due to the specialisation of their staff (Hellmann 2007). Furthermore, it has been shown that the existence of a TTO plays only a marginal, indirect role in driving academics to be involved in start-ups (Clarysse, Tartari, and Salter 2011).

Most of the existing literature on UTTs and the performance of TTOs has been focused on the U.S. case (Shane 2002; Thursby and Kemp 2002; Thursby and Thursby 2002; Lockett and Wright 2005; Heisey and Adelman 2011) and on the UK (Lockett, Wright, and Franklin 2003; Chapple et al. 2005; Meyer and Tang 2007; Siegel et al. 2008; Ismail, Omar, and Majid 2011). However, studies have also been conducted for other countries. For Italy, there are several relevant studies on this topic (Balderi et al. 2007; Fini, Grimaldi, and Sobrero 2009; Muscio 2010; Fini et al. 2011; Algieri, Aquino, and Succurro 2013). There are also studies for other countries, although the focus is not always coincident. Some of these studies include: the analysis of UTT through a K.U. Leuven case study in Belgium (Debackere and Veugelers 2005); a comparison of spin-offs from U.S. and Canadian universities (Kenney and Patton 2001); a regional case study in Canada (Bathelt, Kogler, and Munro 2010); university patenting in Denmark (Baldini 2006); the efficiency of French TTOs (Curi, Daraio, and Llerena 2012); the commercialisation of academic inventions in Germany (Buenstorf and Geissler 2012); the determinants of university patenting and academic incentives in Spain (del Barrio-Castro and García-Quevedo 2009); UTT mechanisms in Sweden (Nilsson, Rickne, and Bengtsson 2010), and; the impact of inventors' royalty share in university patenting and licencing in Portugal and Spain (Arqué-Castells et al. 2016). Most of these papers cover countries where high-tech industries play a significant role.

2.2. The institutionalist approach and the resource-based view

In this paper we analyse the performance of TTOs in the light of both the institutional and resource-based theoretical perspectives.

North (1990), (2005) distinguishes between formal and informal rules when he defines institutions. When adapting the institutional perspective to university entrepreneurship, the distinction of North holds. Formal institutions refer to entities such as TTOs, Science and Research Parks, business incubators, as well as to legislation, and policies such as IPR regulation, the incentive system and the 'publish or perish dilemma', whilst informal institutions refer to aspects such as entrepreneurial culture, networks of innovation, or the entrepreneurial attitude of Faculty and students (Destro 2012).

The relevance of institutional factors related to the nature and structure of the academic organisations has been examined by different authors who have studied TTOs' activities, such as the existence of a medical school. According to Pressman et al. (1995), 60% of university-licenced inventions result from biomedical inventions, and consequently universities with medicine faculties and good health-related research are much more prone to patenting. It has been shown that U.S. private universities are more efficient than public universities with regard to licencing activities (Thursby and Kemp 2002; Thursby and Thursby 2002). Furthermore, the different nature of the organisational culture and motivations of different players involved in UTT have been highlighted, namely: that university scientists are firstly driven by the desire for recognition, and secondarily, by financial gain; whereas TTOs have as their primary motivation the protection and marketing of the intellectual property of the university, with financial gain also playing a role in this process (Siegel, Waldman, and Link 2003).

According to the Institutional Theory, the possible lack of commitment and motivation of academics to pursue patenting and TTO activities in general is a more important obstacle to the commercialisation of technology than existing resources, as professors resist working

with university TTOs, on account of their policies being oriented towards academic work, whereas licencing has little effect on decisions regarding tenure and promotion (Markman et al. 2005). These authors also refer to the fact that delay-of-publication clauses in licencing contracts affect scientists' propensity to disclose their inventions. Furthermore, faculty considerations of the costs and benefits of disclosure are coloured by institutional environments that are supportive or oppositional to the simultaneous pursuit of academic and commercial endeavours (Owen-Smith and Powell 2001).

The Resource-Based View (RBV) adopts a different perspective, stating that TTOs' work is strongly affected by resource constraints. Resources are heterogeneous across organisations (Barney 1991), and have intrinsically differential levels of efficiency (Peteraf 1993). Powers and McDougall (2005) stress that the application of firms' RBV frameworks to academic entities is useful, and examine the activities of universities and TTOs in relation to this perspective, organising the resources available to universities and TTOs into four categories: financial; physical; human capital, and; organisational resources. They point out that the learning curve of the human resources of TTOs is steep, and that institutions with older offices often outperform those with newer offices, due to the longer time period needed to develop the resource of specific skill sets that are useful for technology transfer. Siegel, Waldman, and Link (2003) agree about this learning effect, concluding that older TTOs are more efficient. For Markman et al. (2005), TTO employees need to have a variety of expertise, as they have to evaluate disclosures, negotiate licencing agreements with representatives of clients, and must also interact with both lawyers who specialise in intellectual property and university managers.

Lockett and Wright (2005) use a dynamic view of the RBV in their analysis of spin-off creation, which is comprised of such resources as stock, and capabilities or routines, such as flows or activities. With regard to organisational structure, Bercovitz et al. (2001) point out that, according to a case study of three different U.S. universities, those TTOs that follow a divisional approach are more effective and are more efficient than those that follow a centralised one. Barney (2001) stresses that in order for resources to be a source of sustained competitive advantage, four attributes are needed, in that resources must be: valuable; rare; imperfectly imitable, and; un-substitutable. Faculty and patents are the most obvious resources that are capable of delivering these sustained competitive advantages, and they thus have a powerful influence on the different results of the activity of the various TTOs. Each TTO's performance will also account for its own dynamic capabilities, i.e. its ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments (Teece, Pisano, and Shuen 1997).

Some authors do not see the institutional and resource-based views as necessarily being alternative rationales to account for the performance of TTOs. Markman et al. (2005) defend the complementarity of the institutional and RBV views, stressing that early-stage discoveries and disclosures, which relate directly to the attitudes and behaviours of Faculty, are more crucial than the budgetary and administrative restrictions that TTOs face, whereas during an intermediary stage, the limited availability of resources is a strong impediment to commercialisation. Later in the process, an institutional factor again becomes prevalent, as faculty-inventors appear to play a more positive role in accelerating the process during advanced commercialisation stages.

3. TTOs in Portugal

Portuguese universities have evolved over recent decades towards greater autonomy. They are still funded, to a significant extent, out of the government budget; however, they are increasingly attempting to obtain additional funds, as a result of the continuous cuts in funding and increasing research costs, and they are eager to use all sorts of private sector funding, ranging from student fees to business sources, through to sponsorships or research contracts. Researchers and professors alike are strongly encouraged to disclose their inventions to their universities and TTOs, and to patent their results. The results of such research belong to the university; however, the researchers are entitled to a share of the royalties, which varies from university to university, with a mean value of approximately 50% (Arqué-Castells et al. 2016). Furthermore, researchers are strongly encouraged to be involved in all other sorts of technology transfer.

Despite university extension activities having started in Portugal before 2000, the implementation of a structured network of TTOs only came about after the establishment of GAPIs and OTICs, which occurred, respectively, in 2000 and 2006. Within this study, we have carried out four small illustrative case studies of these different TTO structures, which are presented in an online Appendix.

GAPIs are small structures that were established within universities, technology centres and business associations, with the aim of promoting the use of intellectual property, as an initiative of the Portuguese Patent and Trademark Office (INPI), which provided funding and support. GAPIs are geared for strengthening the competitiveness of Portuguese companies, by encouraging and protecting innovation. The support provided to companies and other entities includes the following actions:

- Clarification of the rules governing the various forms of industrial property, the level of technical requirements, and also administrative requirements and costs;
- Information regarding the legal status of industrial property rights;
- Awareness/information regarding industrial property within the sectors/areas of operation, etc.

These actions were implemented in three phases (2001, 2003 and 2006), and almost half of them were established within universities (10 out of 22).

The first of the four small case studies[1] we have carried out provides evidence about the activities of a GAPI. Case study 1 is about IPN, an association established by the University of Coimbra (UC) – the third largest university in Portugal, back in 1991, which involved local municipalities, firms, trade associations and other institutions. The GAPI inside IPN was created in 2001 with funding from the GAPI initiative. This GAPI works in close liaison with DITS, the UC OTIC, namely in the area of IP services, and both can apply for patents. Usually a more difficult or complicated IP issue will be handed and dealt with by the IPN's GAPI. IPN has a mixed management structure with representatives from the University, trade associations and start-ups, whereas the IPN's GAPI is professionally run by a manager. As IPN has an incubator, the GAPI is very active in supporting spin-off creation as well. IPN's sources of funding are mixed, originating from services and firms, the University, and the City Municipal Council. IPN's GAPI contrasts with other GAPIs, which are mostly very

[1]The four case studies are part of an online Appendix.

small structures operating independently in their respective universities, although always with a strong involvement with INPI.

OTICs are 'entities that mediate knowledge and technology, in order to identify and promote the transfer of innovative ideas and concepts of the entities from the Scientific and Technological System to the business sector', and were established in 2006 by a government organisation, the Innovation Agency, with a one-off funding for a period of 2 years. TTOs have been exclusively implemented in higher education institutions, both at universities, and also at polytechnic institutes. Their goals are to:

- Provide an environment of university-company cooperation, through technology transfer and knowledge sharing in joint projects;
- Identify and disseminate the knowledge potentially relevant for technology transfer in universities;
- Identify the technological demands of the business sector and explore how universities can meet those demands, supporting the promotion of innovative projects and competitive technological development.

Our second case study provides evidence from one of the existing OTICs. DITS, Case Study 2, was set up in 2003, with UC own-funding, anticipating the OTIC initiative funding, and it is a division within the UC Rector's office. It works closely with IPN on entrepreneurship and incubation, and is more involved in the initial stages of ideas, concepts, business plans, etc. and then hands the incubation responsibility over to IPN. DITS, which has had a stable leadership, is very active in seeking patentable material within UC, where invention disclosure is mandatory and granted patents have been considered for faculty promotion and tenure since 2010. DITS interacts strongly with the various UC research groups, where it carries out technology scouting, looking for potentially patentable products and technologies, and supports them by means of initiatives such as 'ignition grants', which can fund further lab tests, prototypes, market studies, etc. DITS' current funding depends exclusively on the knowledge transfer projects it is involved with, at both the national and European level. UC's patent portfolio has been growing steadily, due to both IPN's and DITS' activity.

Our Case Study 3 is also about an OTIC – the IPS OTIC. IPS is the Polytechnic Institute of Setúbal, Setúbal being the region immediately to the south of Lisbon. The IPS OTIC was created with OTIC initiative funding, and was very active in the promotion of entrepreneurship, not only within IPS, but also in the Setúbal region. As polytechnic institutes have no PhD programmes and their number of Master's programmes is limited, most of them have no R&D critical mass, as was the case of IPS. The immediate consequence is that the potential for transfer and patent application has been low. The OTIC was managed by two faculty members, who were both simultaneously studying for their PhD in Management, and who were employed to supervise the OTIC. Despite the difficulties it has faced, this IPS OTIC is still active, although under a different name, due to a very active and committed IPS management.

The activities of GAPIs, which are centred on Industrial Property, and OTICs, which are centred on Knowledge Transfer, are mostly complementary, although their goals are partly overlapping, and both often perform activities which could be seen to be more typical of the other. Strictly speaking, patenting is an aspect of technology transfer, but this latter activity may not always need prior patenting. In a few universities, GAPIs and OTICs have

merged into an integrated organisational structure, which in this paper we call 'integrated structures', henceforth GAPI + OTIC.

This was the case at the University of the Minho (UMinho), the 5th largest university in Portugal. TecMinho, the UMinho's TTO, is our Case Study 4. It was created in 1990, with the mission of developing and transferring knowledge to the business community and other economic and social players, and also to contribute to innovation and entrepreneurship. TecMinho has its own training department, plus a technology transfer department, called DDT, which has three business units: Industrial Property Management, Technology Commercialisation, and Entrepreneurship. Since its inception in 2001, DTT greatly benefitted from the national GAPI programme, and from 2005 onwards it received funding from the national OTIC initiative. DTT's role is to support companies and researchers in the development and marketing of ideas and technologies. Its action focuses mostly on IP management, the licencing of patents and know-how, and in creating and managing R&D partnerships. DTT's turnover stems from S&T commercialisation, IP licencing and entrepreneurship services, with a breakdown, respectively, of about 50, 20, and 30%. DTT has thus been a highly successful case of a 'full' TTO, which has also been due to very professional and stable management.

Portuguese GAPIs and OTICs (Table 3) are among the youngest and the smallest in the world, at least in terms of numbers of staff. If we compare them with those European TTOs surveyed by ASTP and Proton in 2008, they were, on average, only half as experienced, and around a third of the size. In terms of patent applications, Portugal compares unfavourably, with an average close to half of those for other European countries. In terms of licences, the number is as low as 10–20% of the European average, while in terms of spin-off companies, Portugal compares reasonably well, with values close to countries such as Ireland, the U.K., France and Italy, and more than twice the figures for South Korea and Denmark. One should however take into account the fact that part of the observed gap stems from a 'size' effect. If the performance of Portuguese TTOs is standardised, taking into account faculty size, such as in Arundel and Bordoy (2010), we find that Portugal compares favourably with the European averages and that it has similar values to Spain, in terms of both patent applications and the creation of spin-off firms, although the gap remains high for licencing (see Table 4).

Table 3. TTOs: international comparison (mean values per office, all data for 2008 or 2009).

	Portugal (1)	ASTP (2)	ProTon (3)	Spain (4)	France (5)	Italy (5)	South Korea (5)	Den-mark (5)	U.S. (5)	Spain (5)	Ireland (5)	U.K. (5)
TTO Age	4.0	9.3	12.4	14.9	*10.3*	4.0	4.2	10.9	18.5	17.7	5.1	17
Staff number	3.5	10.9	9.7	8.4	6.3	3.8	4.8	5.1	11.0	13.4	3.6	
Patent applications	6.5	14.0	10.0	12.0	3.3	10.5	52.3	9.9	66.9	10.0	6.0	13.3
Licences executed	0.6	10.8	12.4	3.6	1.7	2	6.8	5.7	29.4	3.1	4.2	28.2
Spin-offs established	1.1	3.1	1.6	2.4	1.5	1.6	0.4	0.6	3.3	2.1	1.4	1.5
number of observations	27	71	305	60								

Sources: (1) Our Survey; (2) ASTP survey for fiscal year 2008; (3) Proton Europe survey, FY 2008; (4) CRUE: informe de la eencuesta RedOTRI 2008; (5) The Proton Europe 7th Annual Survey report April 2011.

Table 4. TTOs: international comparison (mean values per office; and standardized per 1000 faculty).

	Portugal (1)		ASTP (2)		Spain (3)	
	mean	stdized average	mean	stdized average	mean	stdized average
TTO Age	4.0		9.3		14.9	
Staff NUMBER	3.5		10.9		8.4	
Patent applications	6.5	10.0	14.0	7.0	12.0	10.1
Licences executed	0.6	0.9	10.8	5.2	3.6	
Spin-offs established	1.1	1.7	3.1	1.5	2.4	1.4
number of observations	GAPIs and OTICs (27)		University KTOs (71)		OTRIs (60)	

Sources: (1) Our Survey; (2) ASTP survey for fiscal year 2008; (3) Informe encuesta RedOTRI 2008.

4. Research questions

Our first research question is whether the diverse nature of the institutions that we are dealing with, namely being a GAPI, an OTIC, or a GAPI + OTIC, determines different behaviours. As highlighted above, the institutional perspective in relation to university entrepreneurship considers, among other aspects, formal institutions such as the TTO, and informal ones, such as the networks of innovation (Destro 2012). In our view, GAPIs and OTICs differ precisely in their own characteristics as TTOs, and also in the networks of innovation in which they are inserted. GAPIs are geared primarily towards the promotion of industrial property (patents, trademarks, etc.) and were funded by INPI, there was a permanent follow-up of their activities, and INPI transferred not only the funds, but also the knowledge they used on IP issues. GAPIs' learning process was very interactive, with both INPI and the other GAPIs creating a sort of informal network. In contrast, OTICs were primarily focused on the transfer of knowledge to companies, and they benefitted from a one-off funding from the Innovation Agency (AdI), which did not participate in the OTICs' learning process, as that learning mostly stemmed from each OTIC's internal dynamics. GAPIs thus had different priorities to those of OTICs the logic of networking being much stronger in the case of GAPIs. Both types of structures were capable of, and even encouraged to work freely along the traditional linear items of a UTT (namely: disclosures, patenting, licencing and spin-off creation), and in both cases global funding vanished after 2008. Naturally, the integrated structures (GAPI + OTIC) have managed their resources in pursuit of both objectives, and they took advantage of a double funding, being able to create some economies of scale, and relying on both the internal dynamics of their University and the GAPI network.

Our assumption behind this first research question is that the institutional nature of the different units we are observing is stronger than the other characteristics of the universities that they belong to, such as staff size, or regional location between more and less developed areas. This assumption will be analysed by using cluster analysis.

The second research question relates to the factors that account for the performance of the surveyed entities. First of all, we have to define performance. Our study of the output performance of Portuguese TTOs concentrates on three variables: university-industry research contracts; licencing of intellectual property, and; the creation of spin-offs. This definition of TTO performance is in line with that of Siegel, Waldman, and Link (2003), Markman et al. (2005), Bercovitz and Feldmann (2006), Caldera and Debande (2010), and Comacchio and Bonesso (2012). Friedman and Silberman (2003) measure the output of

UTTs by using number of licences and start-ups and royalty income, but we were not able to obtain detailed information for the latter variable. Arundel and Bordoy (2008) select as indicators for the actual use of public science discoveries, licences, start-ups and licence revenue, which we have replaced with research contracts.

The rationale for our second research question is in line with the RBV, in the sense that the resources available and the capabilities, or routines, strongly affect the performance of TTOs. TTOs manage resources and engage in activities which, according to their own experience, allow them to generate specific outcomes. Each TTO has access to a set of researchers (Faculty) and their disclosed research results, with the latter being potentially transformed into patents (intermediate outputs). The TTO engages in additional activities, which may be predominantly internal to the university, such as training programmes, or external, such as participation in fairs and exhibitions, involvement in international collaborative networks, or conducting studies commissioned by business entities, using skilled staff and knowledge management tools (databases, specialised IT systems). The use of their resources and the performing of these activities, help TTOs to achieve specific results, namely technology transfer contracts, licencing agreements, or technology-based spin-off companies.

In order to test this assumption – that TTOs' performance depends on the resources under their management – we first used factor analysis techniques, with an exploratory nature, to progress next to the estimation of a model using the Partial Least Squares-Structural Equation Modelling (PLS-SEM) method.

5. Empirical analysis: data, methodology, results and discussion

Questionnaires covering TTOs' resources, activities and outputs were sent to the managers of 10 GAPIs and 22 OTICs by e-mail, in June 2008. Responses were received in July and August. The response rate was 100% for GAPIs, and 91% for OTICs (Table 2). Further clarifications were made by e-mail or by telephone during the days immediately following the receipt of the questionnaires. Additional phone calls were carried out in September 2008, to complement missing information. A report (Godinho, da Silva, and Cartaxo 2008) was written, which contains an analysis of the collected data.

From the information acquired through this survey, 12 variables were identified for cluster analysis. These variables (Table 5) stand for the resources employed, activities, outcomes, plus the TTO's age, and a TTO staff quality index that reflects the staff's graduation rates. We collected other additional information about the university with which each GAPI or OTIC is associated, namely regarding Faculty and the number of research publications, as well as qualitative information concerning issues such as private/public ownership, the existence of a medical school, and location, taking into account whether the TTO sits in a developed or in a peripheral region. These variables were used in the PLS-SEM estimation. From the average values for both entities we can easily see that GAPIs neither abstain from running Technology Transfer contracts or creating spin-off firms, nor do OTICs refrain from patenting the inventions that are disclosed to them (Table 6).

5.1. Cluster analysis

A hierarchical cluster analysis using the standardised values of the 12 variables selected to characterise GAPIs and OTICs was carried out in order to obtain homogeneous groups. The

Table 5. The variables of the study.

		Minimum	Maximum	Mean	Standard deviation
Resources	1. Number of staff working in the unit (FTE)	1	8	3.5	1.9
	2. Existence of a database[1] (dummy variable)	0	1	.67	0.48
Activities (during the previous two years)	3. Number of training[2] activities promoted	0	118	13.5	22.3
	4. Number of studies[3] promoted	0	20	5.1	5.2
	5. Number of networks or international associations in which the unit has been directly involved	0	8	2.5	1.9
	6. Number of fairs, exhibitions or shows in which the unit was present	1	60	6.7	11.3
	7. Number of patent applications	0	95	12.9	19.6
Outcomes (during the previous two years)	8. Number of technology transfer contracts promoted by the unit	0	74	10.4	16.6
	9. Number of licensing contracts of patented technology	0	11	1.1	2.4
	10. Number of technology-based spin-off companies created out of the unit's activities	0	14	2.1	3.1
Additional variables	11. Age TTO in 2008	1	18	4.0	3.8
	12. TTO staff quality index	.3	2.0	1.3	0.4
	13. Faculty during 2007/2008 academic year (FTE)	180	1876	691	403
	14. Public/Private university (DV)	0	1	.07	0.27
	15. Number of publications [4] during 2004–2008	29	8793	2108	2555
	16. Publications per 1000 faculty	21.5	1882.4	465.6	448.5
	17. Patents per faculty	0	57.4	7.9	11.4
	18. Polytechnic school (DV)	0	1	.04	0.19
	19. University location (DV)	0	1	.67	0.48
	20. Existence of a medical school in the university (DV)	0	1	.15	0.36

Notes: [1] information support system to technology transfer activity;
[2] All training activites which were promoted by the TTO (as a co-ordinator or as a partner).
[3] All studies which were promoted by the TTO (as a co-ordinator or as a partner).
[4] Total number of documents published in scholarly journals indexed in Scopus.

Table 6. GAPIs and OTICs: values per type of structure.

	GAPI	OTIC	GAPI+OTIC	Total
Staff	2.4	3.8	5.0	3.5
Database	0.1	0.9	0.3	0.7
Training	15.0	12.1	18.3	13.5
Studies	2.3	5.6	8.7	5.1
Networks	3.1	1.9	4.3	2.5
Fairs	4.1	6.8	11.7	6.7
Patents	23.9	6.3	25.0	12.9
Tec. Transfer	1.4	13.9	11.7	10.4
Licensing	0.4	0.9	4.0	1.1
Spin-offs	1.6	1.6	6.7	2.1
TTO age	6.7	2.0	9.0	4.0
TTO qual	1.1	1.4	1.4	1.3

clustering algorithm that was adopted is the squared Euclidean distance process, following the Ward method (Sharma 1996; Hair et al. 2013). Chart 1 contains the dendrogram derived from the clustering method that was adopted.

Three clusters were established, as follows: C1 with 15 out of 16 OTICs, plus a GAPI; C2 with 6 out of 7 GAPIs, plus one of the integrated GAPI + OTIC and an OTIC; and finally C3, with two out of the three GAPI + OTIC structures, plus one OTIC.

These three groups adhere to the division of the observed entities in accordance with their institutional nature. Only four exceptions to this general rule occurred: in C1 there is one GAPI, but this GAPI coexists with an OTIC in the same university (UBI); in C2 there is one OTIC (from UNL), plus an OTIC + GAPI, this one being a very small structure from a small university (UTAD), and; in C3, there is an OTIC in addition to two larger integrated GAPI + OTIC structures. Apart from these exceptions, the results are broadly in line with the assumption underlying our first research question, thus confirming that different resources, activities and the resulting outcomes are all associated with the distinct institutional nature

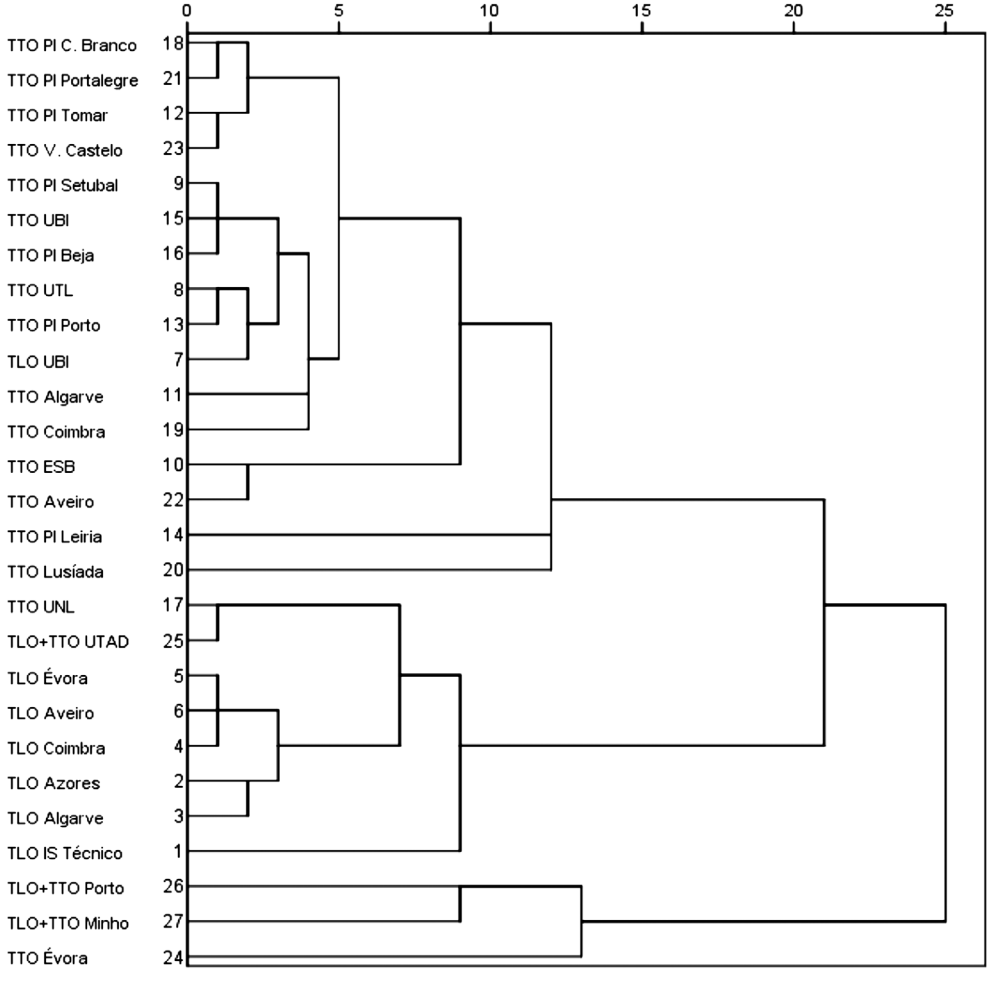

Chart 1. Dendogram (using Ward linkage).

of the observed TTOs. The nature of these different institutions is important, either with regard to formal elements, such as policy and incentive system, which in the case of a GAPI strongly favoured patenting, or with regard to informal ones, such as the network of innovation that they were fitted into, which was again a lot stronger and focused on the case of GAPIs, which prevailed against any other possible aggregation elements.

5.2. Estimation of a PLS-SEM model

We used the PLS-SEM method to estimate a global model, by using a latent variable which measures the performance of TTOs, which is a dimension that is not directly observable, bringing together three output variables: Spin-offs; Technology Transfer, and; Technology Licencing contracts. The fact that the number of observations is very low, and that none of the dependent variables has an approximate normal distribution, are not obstacles to running PLS-SEM,[2] which is robust to these situations, as opposed to covariance-based SEM (Hair et al. 2014), where a detailed explanation of PLS-SEM can be found. In a first stage (measurement model), the various independent variables are replaced by latent variables, which result from their linear combination, whilst a similar procedure is performed for the dependent variable. In a second stage (structural model), the latent dependent variable is linearly regressed on the latent independent variables, using OLS. This analysis requires an explicit specification of factors/latent variables, which we have achieved by using results from correlation and Factor Analysis on the variables listed in Table 5. Some other relevant variables could have been considered, but either they were not available in the survey, or it was not possible to collect the information needed to build them. These variables include: the commercial orientation of the universities (Colombo, D'Adda, and Piva 2010); social networks involving each university (Siegel, Waldman, and Link 2003), and; the amount of industrial and public funding available at the universities (Lockett and Wright 2005; Algieri, Aquino, and Succurro 2013).

The estimation results of the model can be seen in Chart 2. The performance of the GAPIs and OTICs is explained by a set of latent variables. First of all by the University and Technology Transfer dimension, expressed by the number of researchers (Faculty), and the accumulated experience in managing Intellectual Property and Technology Transfer (the age of the TTO). The former dimension assumes that the size of the university research staff determines the amount of knowledge that firms may have access to via TTOs (Colombo, D'Adda, and Piva 2010) (as quoted in Monteiro and Teixeira 2013), while the latter assumes that it is the older TTOs that will benefit from their experience, compared with the younger TTOs, focusing their strategies of technology transfer on engaging the 'best' inventions to be transformed into patents, and hence this becomes a source of income afterwards (Curi, Daraio, and Llerena 2012). The latent variable Research output, which combines both Publications and Patents, suggesting that patenting and publication are complementary rather than being substitutes (Fabrizio and Di Minin 2008), also influence the level of the Outcomes, although their influence is mediated by Faculty and by the experience (age) of the TTO. The direct quantitative influence of the TTO is exerted by a latent variable – TTO Dimension, which is expressed by the number of studies that the TTO has conducted, and by its staff size, as through the enlargement of its critical mass and the specialisation

[2]These arguments are developed in an Appendix provided online on the characteristics of SEM models, PLS-SEM and its use.

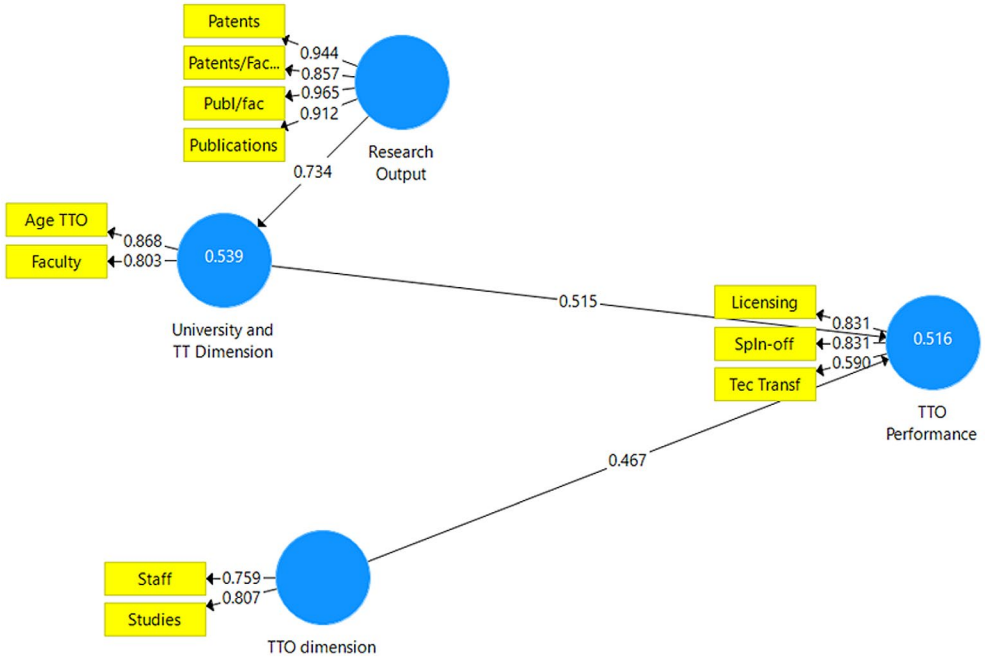

Chart 2. PLS model.

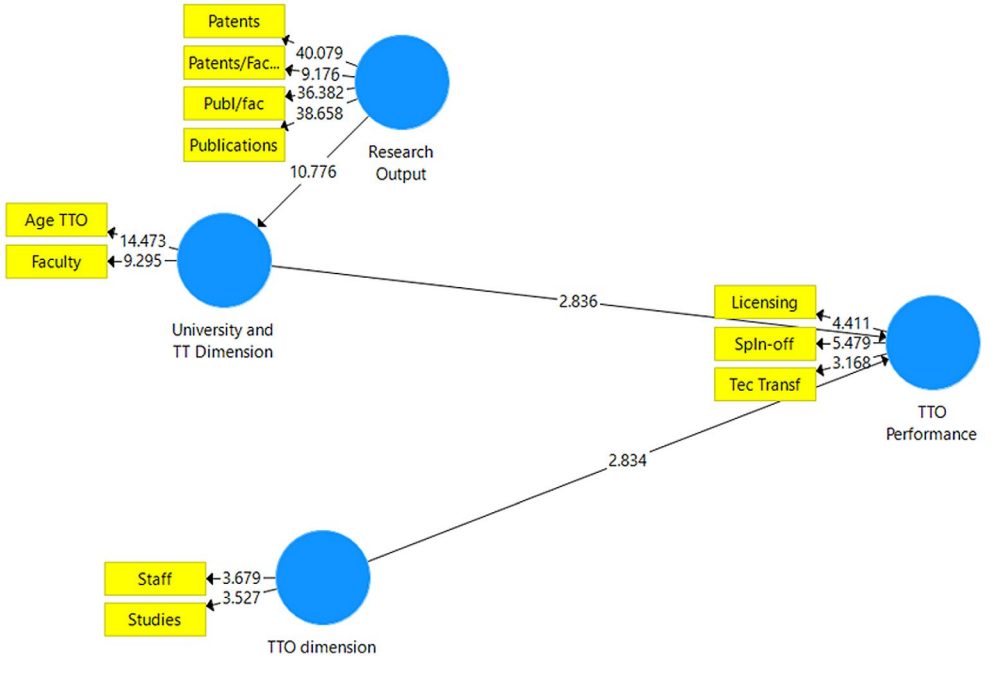

Chart 3. *t* statistics.

it renders, it is possible that a larger TTO size generates better performance (Caldera and Debande 2010).

The coefficients of the arrows connecting the latent variables to the 'indicator' variables (the rectangles in the charts) are correlation coefficients (outer loadings) between the latent variable (factor) and the indicator. The coefficients (Path Coefficients) over the arrows which link the latent variables are similar to the standardised coefficients of the OLS regression model, i.e. they express the variation of the dependent variable when the independent variable varies from one standard deviation. All of the relationships are statistically significant (bootstrapping), at a 1% level (Chart 3).

With regard to the measurement model, the outer loadings are generally very high, with only one case falling below the level indicated as being advisable (0.708), but this is well above the level recommended for exclusion (0.4). The Average Variance Explained (AVE), or communalities, are all above, or equal to 0.5 (Table 7), whilst the measures of reliability of the latent variables are all above the threshold. All constructs fulfil the Fornell–Larcker criterion, which establishes that the square root of each construct's AVE should be greater than its highest correlation with any construct (Table 8). The analysis of the loadings shows that the outer loadings, even when the value for Technology Transfer contracts was slightly below the advisable threshold, are always much higher than the correlations of the 'indicator' with the other latent variables (cross-loadings), as is desirable.

The r^2 (Chart 2), with a value of 0.516, stands at a 'moderate level'. The values of the Path Coefficients are all positive, as expected. The various parameters are statistically significant, as shown by the t-ratios obtained by bootstrapping (Chart 3). Collinearity does not exist,

Table 7. Quality indicators.

Latent variable	Average variance explained	Composite reliability
TTO performance	0.576	0.8
Research output	0.847	0.957
TTO dimension	0.614	0.761
University and TT dimension	0.699	0.823
Threshold	0.5	0.708

Table 8. Discriminant validity.

	TTO performance	Research output	TTO dimension	Univ. and TT dimension
TTO performance	**0.759**			
Research output	0.231	**0.92**		
TTO dimension	0.502	−0.163	**0.784**	
Univ. and TT dimension	0.547	0.735	0.067	**0.836**
		Outer and Cross Loadings		
	TTO performance	Research output	TTO dimension	Univ. and TT dimension
Age TTO	0.537	0.625	−0.002	**0.868**
Faculty	0.364	0.605	0.125	**0.803**
Licensing	**0.831**	0.075	0.387	0.339
Patents	0.146	**0.944**	−0.273	0.618
Patents/Faculty	0.066	**0.857**	−0.397	0.468
Public/Faculty	0.259	**0.965**	−0.117	0.711
Pubications	0.311	**0.912**	0.053	0.817
Spin-offs	**0.831**	0.343	0.436	0.624
Staff	0.374	−0.25	**0.759**	−0.041
Studies	0.412	−0.017	**0.807**	0.137
Tec. Transfer	**0.59**	−0.077	0.301	0.047

Note: Bold values express the square roots of the AVE of the latent variable.

Table 9. Total effects on TTO performance.

University and TT dimension	0.515	Thresholds:	large	0.35
TTO dimension	0.467		medium	0.15
			small	0.02
Research output	0.378			

Table 10. Effect size and predictive relevance.

Effect size (f2) on TTO performance		Predictive relevance (blindfolding)
TTO dimension	0.45	
		0.178
University and TT dimension	0.547	
Thresholds:	Large	0.35
	Medium	0.15
	Small	0.02

as each predictor's (VIF) is around 1 – well below 5. The analysis of the total effects of each latent variable on the outcomes variable shows a strong contribution of the three latent variables: University and Technology Transfer Dimension; TTO Dimension, and; Research Output, in this order (Table 9). The effect size, being the contribution of each of the exogenous constructs to the r^2 of the endogenous construct (TTO Performance), is strong in both cases. With regard to the predictive relevance, the results produced by a 'blindfold' routine show that the average prediction capacity of the model is medium (Table 10).

Summing up, we conclude that this model satisfactorily explains the performance of the TTOs under study.

6. Concluding remarks

Drawing on institutional theory, the first research question was whether the diverse nature of institutions determines different behaviours. This assumption was tested through a cluster analysis, which produced three main clusters, broadly reproducing the institutional nature of the TTOs involved: GAPIS; OTICs, and; integrated OTIC + GAPI structures. These results confirm our initial assumption that the institutional nature of the entities influences their behaviour. This is in no way a trivial result. We could have expected the clustering algorithm to have generated a cluster with the TTOs of the big universities, vs. another with the smaller universities, or otherwise a cluster with the TTOs located on the more developed regions, vs. another with those located in the peripheral regions. This is not what happened, as it was indeed the nature of the organisation and of its initial funding that prevailed. The explanation for why this occurred might lie with the fact that GAPIs' funding was closely followed by INPI – the entity that founded and funded them initially, and which provided specialised training and other support. In this way, a co-evolution of the GAPIs was possible, which rendered each of them to be more similar to the remaining ones. On the contrary, this was not what occurred with the OTICs, which benefitted from a one-off funding from the Innovation Agency. This may account for GAPIs doing better for patenting, while OTICs do better for technology transfer contracts and licencing.

Interestingly, universities where GAPIs and OTICs were merged, present the best average results for all output variables, including patent applications.

The second research question that was studied relied on an application of the resource-based perspective to universities. The analysis we carried out confirmed that the outcomes that represent performance are accounted for by both the resources employed and the activities pursued. This result follows the finding of Lockett and Wright (2005), in that resources (static view) and capabilities (flows or activities) explain different levels of spin-offs. Our PLS estimation confirmed the validity of a model where outcomes depend on: staff employed by the TTOs; university size (as measured by Faculty); TTO experience; Patent applications, and; Studies. These results are generally in line with previous research on UTT and they indicate that the assumption underlying our second research question was correct.

The merit of the study presented in this paper stems from providing both a conceptual framework grounded on relevant theoretical complementary perspectives, and an insight on UTT implementation in an economic context different from those where such activities had been developed earlier on, such as in North America and in the more developed European economies. Although we recognise shortcomings in our analysis, the results that were obtained clearly contribute to the literature on university technology transfer by illustrating how the institutional configuration of TTOs and the resources used all interact with their activities and performance. Furthermore, we think that the methodological strategy that was followed can easily inspire similar studies on UTT, regardless of the development level of the context under consideration.

An obvious limitation to this study is that it was based on data that is almost a decade old now. As the data was confined to the years of 2006–2008, it is possible that the current TTO network has evolved, with the distinction between GAPI and OTIC no longer being relevant. In short, it is possible that the institutional frameworks are not the same, and that the resources allocated to both TTOs and Universities have evolved. Nevertheless, the fact that we focused on the initial stages of UTT formalisation has the advantage that other regions or countries willing to set similar structures may look to this experience to draw lessons for their own cases. Particular inferences may understandably be drawn for those economies that share specialisation patterns closer to that of Portugal, notably in East and Central Europe, Latin America and Asia. We have analysed a first decade of the establishment of a network of TTOs, which had not yet reached cruising velocity, and thus this study is therefore more relevant for contexts where this type of institutional arrangement has not yet matured completely.

In addition to the necessity to update data, future research could further investigate the role that issues such as TTOs' funding regimes, governance, location and dynamic of integration with local economies play in the relative success of UTT in each case. Particularly important in this regard would be to understand how results from academic research may connect better with regional or national demand conditions, or with the existing economic specialisation and structure of the knowledge base, including the diversity and maturity of existing technologies. Finally, it would be critical to further analyse the universities where these units operate, namely their disciplinary specialisation, and the volume and quality of their scientific activities.

In drawing implications from our analysis, we must take into consideration the policy context of our object of study. As can be seen above, the establishment of GAPIs and OTICs in Portuguese universities and polytechnic institutes was connected to programmes and

funding by both the national patent and trademark office, and the Portuguese Innovation Agency. The fact that the learning curve for this type of entity is steep, with performance improvement occurring on a broad horizon, and that the break-even point is usually reached during the medium term (5–7 years in the U.S.), suggests the need for sustained government financial support and other support in order to consolidate positive results, which did not happened in Portugal, as only limited funding, in value, in scope, and in time, was available later on with the advent of GAPI 2.0, GAPI 3 and UTEN. The immediate result was a drop in the growth of both patent applications and grants, as seen in our analysis, and the very limited amounts of licencing revenues collected by the universities (Arqué-Castells et al. 2016). Improvements on the governance side may also be sought, through providing specific incentives in the statutes that regulate the advancement of university careers, which presently focus mostly on academic achievement. Additionally, it would also be advisable in the future to improve the critical mass of the existing TTOs, through the integration of downstream and upstream activities, as has been carried out by some universities with joint GAPI + OTIC structures, or through the coordination of offices belonging to different universities.

As implicated above, the conclusions of our analysis are naturally relevant for contexts where university technology transfer has not yet reached maturity, and where the economic structure may have similarities to the Portuguese one. However, our analysis highlights issues that also have relevance for more developed economies. The consideration of our results may help both policy-makers and universities managers alike reflect on the best orientation of TTOs' activities – whether they should concentrate further upstream (patenting), or downstream (joint contracts, spin-offs), or both, or rather on the adequate size and resources to allocate to these structures, or on how they can obtain learning economies from networking and resources sharing. Furthermore, the reduction in university patenting that occurred in Portugal after public policies withdrew the initial funding of GAPIs and OTICs, raises other considerations related to the patenting strategy of universities, and whether they should focus on a few patents with higher potential, rather than on having wider patent portfolios. Patenting by universities involves not only considerations of possible return and financial gains, but also, to a large extent, considerations of reputation and visibility. Also relevant is the question of identifying the markets where protection has to be sought, and more critically, how technology can be licenced in these markets.

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No potential conflict of interest was reported by the authors.

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