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Manuel Mira Godinho, Rui Cartaxo

Cities and Innovation

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Manuel Mira Godinho, Rui Cartaxo

Postal Address:
Institut d'Economia de Barcelona
Facultat d'Economia i Empresa
Universitat de Barcelona
C/ Tinent Coronel Valenzuela, 1-11
(08034) Barcelona, Spain
Tel.: + 34 93 403 46 46
Fax: + 34 93 403 98 32
ieb@ub.edu
http://www.ieb.ub.edu

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ABSTRACT: The paper assesses the performance of the technology licensing offices (TLO) and technology transfer offices (TTO) which have been active in Portuguese higher education institutions. Data stemming from a survey of these entities was analyzed in successive steps through factor analysis, cluster analysis and estimation of a model using the Partial-Least Squares methodology. It is shown that the institutional nature of each of the surveyed organizations implies different behaviours and outcomes. Further it has also became clear that the type of resources and activities in the surveyed organizations determine both their "primary outcome" (patent applications and technology transfer processes) and their "final outcome" (technology licensing contracts and technology-based spin-offs). The results of this paper might be particularly relevant for other similar economies as Portugal where high-tech and knowledge-intensive industries have not been dominant.

JEL Codes: O32, O34, I23

Keywords: technology transfer; university-industry relationships; university patenting; university spin-offs

Manuel Mira Godinho
UECE and ISEG/UTL
(Economics and Business School of the Technical University of Lisbon)
E-mail: mgodinho@iseg.utl.pt

Rui Cartaxo
ISEG/UTL
(Economics and Business School of the Technical University of Lisbon)
E-mail: r.car@sapo.pt

1. Introduction

The purpose of this paper is to assess the performance of the technology licensing offices (TLO) and technology transfer offices (TTO) which have been active in Portuguese higher education institutions. No such work has been done before for Portugal, and we assume that it might be relevant for other similar economies this analysis on how TLOs and TTOs perform in an economic context where high-tech and knowledge-intensive industries have not been dominant.

The data used in this paper stems from a survey conducted on request of the Technical University of Lisbon TTO in 2008 and refers to the period 2006-2008. The survey focused on two types of entities, the GAPIs[1] (Offices for the Promotion of Industrial Property) and the OTICs[2] (Technology and Knowledge Transfer Offices). In a few institutions these two types of entities have merged into one, which means we will be analyzing three groups: the TLO group, the TTO group and the mixed TLO+TTO group.

The paper deals with two hypotheses. The first one is that the diversified institutional nature of the surveyed organizations (TLO, TTO and integrated structures TLO+TTO) implies different behaviours and outcomes. The second one is that the resources and activities in the surveyed organizations determine both their "intermediate outcomes" (patent applications and technology transfer processes) and their "final outcomes" (technology licensing contracts and technology-based spin-offs).

The paper is structured into five sections. Section 2 presents a brief survey of the literature on technology transfer from universities to companies and on the activities of TLOs and TTOs, taking into account our specific empirical object. Section 3 identifies the purpose and scope of the study, describes the survey, the data and the variables of the study, outlines the methodology and finally presents the two main hypotheses to be investigated. Section 4 contains the results generated in successive steps through factor analysis, cluster analysis and estimation of a model using Partial-Least Squares. To close, section 5 highlights the main conclusions and puts forward a few recommendations.

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[1] GAPIs stands for Gabinetes de Apoio à Promoção da Propriedade Industrial.
[2] OTICs stands for Oficinas de Transferência de Tecnologia e Conhecimento.

2. Conceptual Framework

a) Technology transfer, licensing and spinning-off in an academic context

Technology transfer has been defined as "... the movement of know-how, technical knowledge, or technology from one organizational setting to another… (Roessner, 1996). For Thursby & Thursby (2002) the transfer of technology is a production process occurring in three stages: (i) an initial phase of development (invention disclosure) by the inventors, when they "... believe that the results of research have commercial potential"; (ii) followed by a phase of patent applications, if they believe" that their knowledge can be patented and licensed"; and (iii) a final stage of licensing.

According to Bozeman (2000), the logic of the university technology transfer to companies is straightforward: "universities and government labs make, industry takes". Moreover, universities seem to have a decisive advantage over government laboratories and other entities as they have students, which are "a reservoir of cheap labor supporting university research […] and a means of technology transfer through postgraduate job placements" (Bozeman, 2000).

Powers and McDougall (2005) point out that "traditionally the mechanism by which the university has developed and commercialized a technology has been via the licensing of an intellectual property to a large, established company who ultimately develops the technology into a saleable good". In contrast, Powers and McDougall (2005) stress that "a growing trend among universities, however, is to pursue riskier paths for technology transfer through the formation of start-up companies or licenses with young, unproven firms."

Bercovitz and Feldman (2006) describe in detail the licensing university "which provides the right for companies and others to use intellectual property in the codified form of either patents or trademarks." According to them, "contractual licensing agreements involve selling a company the rights to use of a university's inventions in return for revenue in the form of up-front fees" and the regular payments of royalties.

Further Bercovitz and Feldman (2006) characterize university spin-offs, pointing out to various possible definitions for “spin-offs”: "firms formed by university, faculty or staff; firms formed around a university license of intellectual property; start-up firms that have joint research projects with the university; and firms started by students or post-docs around research conducted at the university".

According to Cervantes (2003), the answer to the question faced by managers of technology transfer and inventors of choosing between licensing a technology or creating a start-up, depends on the nature of the technology to be transferred, the market for this technology and the institution's mission. Focusing on the technology’s characteristics, Mamede and Godinho (2005) point out that the "characteristics of the technology and of the knowledge base […] affect the rate of spin-off. The discussion of issues such as tacit vs. codified technology would certainly be a promising line of research." Following such perspective, one may infer that technologies most likely to be codified or patented are more likely to be licensed, while technologies with a more intense tacit dimension are more likely to be exploited by start-ups originated in universities (spin- offs).

b) The role of the TLOs/TTOs

In the process of universities’ technology transfer the Technology Transfer Offices (TTOs) are active intermediaries between the administrations of universities, teachers and business firms. They perform a systematic survey of existing research and knowledge within the universities, encourage researchers to look for technological opportunities in their research and disclose their discoveries to the TTO, and promote and offer the technologies they identify as having market value to potential users. For Markman et al. (2005) "the process of commercialization of technologies developed at the university include the inventions, the disclosure of inventions to a university TTO, the assessment of patentability and attempt to transfer and license the IP for the industry."

This mediating effect of TTOs is stressed by Siegel et al. (2003), for whom an important responsibility of senior staff in the TTO would be helping in establishing the connections through “boundary spanning”, which “refers to actions taken by university technology managers to serve as a bridge between “customers” (entrepreneurs/firms) and “suppliers” (scientists), who operate in distinctly different environments. Without effective boundary spanning, the needs of customers may not be adequately communicated to suppliers."

According to Macho-Stadler et al. (2006), TTOs would be instrumental in developing relationships with industry: "A dedicated transfer unit allows for specialization in support services, most notably, partner search, management of intellectual property and business development." A TTO "can be interpreted as a seller that brings together technology inventions from different research laboratories within a university. The TTO would be like a *technology seller* and would help to "reduce the problem of asymmetric information". TTOs are instrumental in reducing the asymmetry of information between industry and science on the value of inventions as companies are not normally able to assess the quality of inventions *ex-ante*, and as inventors may have difficulty in assessing the business value of their inventions, particularly when they arise in newer technology areas (Markman et al. 2005).

As Macho-Stadler et al. (2006) pointed out an important dimension of the TTOs’ mission has to do with the management of intellectual property (IP), which often involves patenting but may also involve protection through industrial designs or trademarks. A first step in this process of IP management is to seek protection for the inventions. Patenting has now become a common activity for many universities, which have been building up larger patent portfolios. These university patenting activities were stimulated by the context set by the enactment of the Bayh-Dole Act in the US in 1984, but they are part of a broader development which has do to with the emergence and growth of science-based technologies such as IT, microelectronics, biotechnology and nanotechnology (Mowery and Sampat 2005). The relevance of IP for universities has been such that in some cases they have constituted Technology Licensing Offices

(TLOs), thus signaling a possible focus on a more upstream stage of the technology transfer process.[3]

c) The institutional and resource based views

In this paper we will discuss the performance of TTOs within the scope of both the institutional and resource based theories. The relevance of institutional factors related to the nature and structure of the academic organizations, such as the existence or not of a medical school, has been examined by different authors. As Pressman et al. (1995) point out "60% of university licensing inventions result from biomedical inventions", thus making schools with medicine faculties and good health-related research much more prone to patenting. Siegel et al. (2003) stress the importance of "the different nature of organizational culture and motivations of different actors" involved in university-industry technology transfer. Specifically, according to this perspective the university scientists would be driven by the desire for recognition and secondarily by the financial aspects, while the TTO would have as the primary motivation the protection and marketing of intellectual property of the university, resulting in the facilitation of technology diffusion, with financial motivation playing a role in this process.

For institutional theory, the possible lack of commitment and motivation of academics for patenting and the TTO activities in general is a more important obstacle to the commercialization of technology than the existing resources: "teachers resist working with the university TTO because the policies are oriented to academic work, while the licensing activity is seen as "service", weighing little in the decisions of tenure and promotion" (Markman et al., 2005). Godinho and Mamede (2005) also refer to the "dilemma" faced by the researchers, among the immediate publication of the results of their investigation and awaiting the outcome of the patenting process. Delay-of-publication clauses in licensing contracts are referred to by Markman et al. (2005).

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[3] As we shall see in later sections of the paper, it is expected that the activities of GAPIs, given the nature of its main object, industrial property, are more focused on patenting, while the OTICs activities are more oriented towards technology transfer through contracts for technology licensing and university spinning-off. Further it is expected that the integrated structures OTIC+GAPI follow both upstream and downstream activities with similar intensity.

In contrast, according to the resource based view (RBV), the TTO work is strongly affected by resource constraints. Powers and McDougall (2005) stress that "although the resource-based view of the firm was largely developed from studies of the for-profit sector, its application in higher education is useful for sharpening our understanding of organizational phenomenon, such as technology transfers that occurs there". They examine the activities of universities and TTOs in accordance to this perspective, grouping the resources available to universities and TTOs in four categories: financial resources, physical resources, human capital and organizational resources. They point out that the learning curve of human resources of the TTO is steep, stressing that "the technology transfer literature suggests that institutions with older offices often outperform those with newer offices, perhaps due to the longer time period needed to develop the resource of specific skills sets useful to facilitating technology transfer". For Markman et al. (2005) TTO employees "have to evaluate many revelations, negotiating licensing agreements with representatives of potential and existing clients, and interact with lawyers specializing in Intellectual Property and university administrators."

Powers and McDougall (2005) find that "conceptualizing of universities as being in a competitive environment with their peers is appropriate". In this light, Barney (1991) stresses that for resources to "hold the potential of sustained competitive advantages" four attributes are needed: the resource must be valuable, rare, imperfectly imitable (in the sense that "the organizations which don't possess these resources cannot obtain them") and not substitutable, meaning that "there must be no strategically equivalent valuable resources that are themselves either not rare or imitable". Faculty and patents are the most obvious resources capable of delivering these sustained competitive advantages and would thus have a powerful influence in the different results of the activity of the various TTOs/TLOs.

Some authors, however, do not see the institutional and resource based views as necessarily alternative rationales to account for the TTOs performance. That is the case of Markman et al. (2005) that point out to the complementarity of the institutional theory and the resource based view, albeit stressing that the crucial stage of "discovery and disclosure of discovery" that relates directly to the attitudes and behaviors of academic staff is more crucial than the budgetary and administrative restrictions that TTOs face. This complementarity is more obvious if we reckon, as Markman et al. (2005) write “during early stage, limited availability of resources…is a strong impediment to commercialization” but it is an institutional factor that late in the process becomes prevalent as “during advanced commercialization stages to new ventures, faculty-inventors seem to play a more positive role in accelerating the process”.

3. Scope of the analysis, hypotheses and methodology

This study analyzes the units in charge of technology licensing and transfer that have been set up in Portuguese higher education institutions. There are two maim types of such units, the GAPIs and the OTICs, which perform, respectively technology licensing and technology transfer activities.[4]

The GAPIs were established within universities, technology centers and business associations, with the aim of promoting the use of intellectual property and were an initiative of the National Institute of Industrial Property (INPI, see www.inp.pt). GAPIs were implemented as of 2001, in three phases (2001, 2003 and 2006). Almost half of all the GAPIs created since 2001 were established within universities (10 out of 22).

The OTICs are "entities mediating 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" and were established as of 2006 by the Portuguese Innovation Agency (AdI, see www.adi.pt). OTICs have been exclusively implemented in higher education institutions, both in universities and in polytechnic institutes.

The GAPIs and the OTICs activities are mostly complementary, but often the goals of both entities are partly overlapping. In a few Universities, GAPIs and OTICs have merged into an integrated organizational framework.

[4] GAPI stands for Gabinete de Apoio à Promoção da Propriedade Industrial, while OTIC stands for Oficinas de Transferência de Tecnologia e Conhecimento.

Questionnaires were sent to all GAPIs (10) and OTICs (22) by e-mail in June 2008. Responses were received in July and August. The response rate was 100% for the GAPIs and 91% (20 out of 22) for the OTICs (see Table 1). Further clarifications were made by e-mail or by telephone in the days immediately after receiving back the questionnaires. Additional phone calls were carried out in September 2008 to complement missing information. A report (Godinho, Silva and Cartaxo, 2008) was written containing the basic analysis of the collected data. Such report was done on request of the OTIC of the Technical University of Lisbon (UTL) that commissioned the study and survey to CEGE (a research center at ISEG-UTL).

From the Information collected through this survey, we identified 10 relevant variables for analysis. These variables account for i) the resources employed, ii) the activities and iii) the outcomes of those activities, as expressed in detail in Table 2.

The first hypothesis under study is that the diverse nature of the institutions (GAPI, OTIC and merged GAPI+OTIC) determines different behaviors. Specifically, we assume those behaviors are determined by the type of structure and its objectives: the GAPIs, implemented by the National Institute of Industrial Property, are geared towards the promotion of industrial property (patents, trademarks, etc.), while the OTICs, implemented by the Innovation Agency, are primarily focused on the transfer of scientific and technological knowledge for business companies. Naturally the integrated structures (GAPI+OTIC), manage their resources in pursuit of both objectives. This hypothesis will be tested through cluster analysis.

The second hypothesis relates to the factors accounting for the outcomes of the activities of the surveyed entities. The theoretical model from which we start from is quite simple: GAPIs and OTICs manage <u>resources</u> with which they engage in <u>activities</u>, therefore producing results in the form of specific <u>outcomes</u>. The main resources are manpower (skilled staff) and knowledge management tools (databases, specialized IT system). Those activities might be predominantly internal to the university, such as training programs, or external, such as participation in fairs and exhibitions, involvement in international collaborative networks or conducting studies to business associations. The use of these resources and the performing of these activities allow them to achieve <u>results</u> that are more upstream (<u>intermediate outcomes</u>), as is the case of patent applications and technology transfer processes, or more downstream (final outcomes), resulting in technology licensing agreements or technology-based spin-off companies. In order to test this hypothesis we will start by using factor analysis techniques, with an exploratory nature, to progress finally to the estimation of a model using the Partial Least-Squares (PLS) method. PLS was selected as the small number of observations and their distribution rule out alternative methods.

4. Results and discussion

a) Cluster analysis

A cluster analysis was carried out in order to get a set of homogeneous groups. The hierarchical cluster analysis was performed using all 10 variables, which had previously been standardized so that they would all contribute equally to the solution. An agglomerative clustering analysis was performed using the (SPSS default) squared Euclidean distance (SEUCLIDIAN). The results obtained using both the “average linkage within groups” method, the “complete linkage” method and the Ward method are very similar leading to almost identical clusters. Chart 1 contains the dendrogram stemming from the Ward method.

To determine the number of appropriate clusters, Pestana and Gageiro (2005) and Maroco (2007) suggest using both the criteria i) of the growth of the distances between clusters and ii) of the "r squared" (r^2). The 1st criterion is applied directly to the "agglomerations coefficients" whose evolution with respect to the value of the last cluster is shown below after "normalization". In theory, from the point of view of the evolution of the distances, the optimal number of clusters occurs when there is a significant decrease in the rate of decline of the distances, i.e. when the slope of the curve becomes small. In what regards the 2nd criterion, r^2 measures for each variable the ratio between the sum of squares between groups (SQC) and the total sum of squares (SST). Specifically, we are looking for a number of clusters when a steep rise in the r^2 occurs. Given this objective, we have run SQC and SQT ANOVA for each variable, for one cluster solution, two clusters, etc. up to 10 clusters, determining the r^2 for the sum of the 10 variables. As the slope of the line for the distances between clusters progresses smoothly, the r^2 criterion becomes crucial as it shows a somewhat significant rise in the transition from 7 to 8 clusters, when it achieves 85% (see chart 2).

Accepting this number of 8 clusters, it is possible to understand that they are part of three larger groups:

1. A group of 7 elements which integrates 5 GAPI (Azores, Evora, Coimbra, Aveiro and Algarve), together with one integrated structure (GAPI+OTIC UTAD) and the OTIC UNL. Further, the GAPI IST would join this group at a later agglomeration stage.
2. A group of 12 elements which integrates all the polytechnics' OTICs with the exception of the OTIC IPL, both the OTIC UBI and GAPI UBI, and the OTICs from Algarve, Coimbra and the UTL. A small cluster of 2 elements, with OTIC USB and OTIC Aveiro, is located very close to this cluster and would join it at a later stage of the agglomeration process as well.
3. Finally, there is a small cluster of the integrated structures (GAPI+OTIC) of Minho and Porto

The remaining OTICs (Évora, Lusíada and IPL) remain isolated.

These three groups reproduce roughly the "natural" structure of GAPI, OTIC and GAPI+OTIC clusters. In order to assess the statistical adherence of these 3 "natural" groups we have performed a Discriminant Analysis (DA) assessing this "natural" structure. This DA has led to the choice of 2 discriminant variables, "Database" and "Spin-off", with an 89% right "prediction" of cluster membership. The DA "fails" only in few cases, placing the GAPI+OTIC UTAD and the OTIC UNL in the GAPI cluster and vice-versa placing the GAPI UBI in the OTIC cluster. These results are thus broadly in line with our first hypothesis.

b) Factor analysis

The analysis of the 10 variables set of the Inquiry is likely to be facilitated through techniques of exploratory data analysis, such as Factor Analysis (FA), to "discover and analyze the structure of a set of interrelated variables in order to construct a scale to measure intrinsic factors that somehow control the original variables" (Maroco, 2007).

We have performed a FA to determine the appropriate number of factors.[5] The application of the Varimax method of factors' rotation (completing the so-called "Little Jiffy"), which assumes that the factors are orthogonal and aim at each variable being strongly associated with a single factor, generated four factors. Each of those four factors is associated with a pair of variables (*Staff* size and *Database*; *Technology Transfer* processes and *Technology Licensing* contracts; *Studies* and *Spin-offs*; *Networks* and *Trade Fairs*) while the variables *Patents* and *Training* activities came up without being part of any of the two factors.

As the KMO statistic was well below the threshold of 0.5 we ran successively the FA excluding *Training*, *Patent* and both, with the statistical indicators summarized below. The analysis excluding both *Patent* and *Training* is statistically acceptable in the light of all criteria, with the exception of KMO, but by a small margin in this latter case (Table 3).

The FA for the 8 variables that were retained is summarized in the table below. The factors that were generated are precisely the same which had been derived before by applying FA to all variables, namely a factor (2) associated with the quantity of *Resources* (containing the variables *Staff* size and *Database*), a factor (1) for *Technology Transfer* (with the variables *Technology Transfer* processes and *Technology Licensing* contracts), a factor (3) connected to *Entrepreneurial activities* (with the variables *Studies* and *Spin-offs*) and a factor (4) linked primarily to a *Marketing* dimension (with the variables *Networks* and Trade *Fairs*) (Table 4).

c) Estimation of a model accounting for the *Outcomes*

As pointed out above, the 10 variables we consider in this study reflect 3 different dimensions, namely the *Resources* used (2 variables), the *Activities* (4 variables) and the *Outcomes* (4 variables). Given our 2nd hypothesis, we have proceeded to investigate to what extent the *Outcomes* of the observed entities are explained by the other variables, either the *Resources* or the *Activities* pursued.

We have thus proceeded to the estimation of a global model accounting for the *Outcomes*. There are two fundamental obstacles to the use of OLS to estimate the

[5] FA is available in SPSS with a default the of principal components method, which has the great advantage of not assuming the normality of variables to be studied, and the criterion of eigenvalues larger than 1 (Kaiser criterion)

model: firstly, none of the dependent variables has an approximate normal distribution and, secondly, the low number of observations, 27 compared to a total of 10 variables, results in both a reduced number of degrees of freedom and possible multicollinearity.

We have thus used the PLS (Partial Least Squares) method. PLS is a method that combines regression techniques with factorization of both the independent variables and dependent variables. PLS, or "Projection to Latent Structures", replaces, by the principal components method, the various independent variables by latent variables. A similar procedure is performed for the dependent variable. It is in this sequence that finally the latent dependent variable is linearly regressed on the latent independent variables. The "path model"[6] analysis (using Smart PLS software) demands an explicit specification of factors/latent variables, and, in our case, we have used a "reflective" approach, where each of our 10 original variables is an "indicator" of the respective latent variable.

We took as a starting point our theoretical model concerning the three latent variables, *Resources*, *Activities* and *Outcomes*. The initial results showed however that the *Training* variable presents a negative correlation with the latent variable for *Activities* and the *Patents* variable also presents a negative correlation with the latent variable *Outcomes*.

As a second step we used the structure highlighted by the factor analysis carried out above taking as latent variables the 4 factors (*Resources*, *Marketing*, *Technology Transfer* and *Entrepreneurial* activities) while assuming *Patents* and *Training* as exogenous variables. The *Entrepreneurial activities* variable was used as an endogenous variable. This model was statistically valid but was not very helpful in accounting for the *Outcomes*.

After successive changes of specification and estimation of the model it became clear that the *Training* variable had a systematic negative correlation with both latent variables (*Activities/Marketing* and *Outcomes*) and was therefore excluded from the

[6] *According to Garson (2009), the PLS models are divided broadly into regression models and path models. Also according to Garson (2009), PLS regression models are an alternative to OLS, while the path models model the relationships between latent variables and are an alternative to structural equation modeling (SEM), with the added advantage of being estimable for a smaller number of observations. The path models then enjoy the double advantage of joint estimation of the endogenous variables and this can be accomplished with the limited number of observations that were available*

analysis. *Patents* were also presenting a negative correlation with the *Outcomes* latent variable and were therefore separated from the other variables included in this Outcomes dimension. We have thus finally reached an acceptable specification of the model (see chart 3).

The coefficients within each latent variable (the blue circles in the charts) are coefficients of determination (r^2), the coefficients of the arrows connecting the latent variables to those variables` 'indicators' (the yellow rectangles in the charts) are correlation coefficients between the latent variable (factor) and the indicator (outer loadings), and the coefficients (Path Coefficients) over the arrows which link the latent variables are similar to standardized 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.

The r^2, with a value of 0.39, stands at a "moderate level".[7] The correlations of the different indicators with their respective latent variables (the *outer loadings*) are generally high, with only two cases falling below the level indicated as advisable (0.7) but well above the level recommended for exclusion (0.4). The values of the Path Coefficients are all positive, as expected. The measures of reliability of the latent variables are all above the indicated threshold of 0.7 while, on the other hand, the AVE (or communalities) are all well above 0.5 (Table 5).

The analysis of the loadings shows us that without exception the correlations between each "indicator" and its latent variable, the outer loadings, even in cases where this value was slightly below standard (*Trade Fairs*, *Marketing* and *Technology Transfer*, *Outcomes*) are always much higher than the correlations of the "indicator" with the other latent variables (cross-loadings), as it is desirable (Table 6).

The full effects of the different latent variables on *Outcomes*, which are equal to the sum of direct effects (Path Coefficients) with indirect effects (the product of direct effects among variables) are sound, with an emphasis on the level of *Resources* and *Patents* (Table 7).

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[7] This is so if we take 0.19 as the standard for "low level", 0.33 for "moderate" and 0.67 for "substantial".

The various parameters are statistically significant, as shown by the t-statistics, obtained by bootstrapping (see chart 4).

Summing up, it is possible to say that this model explains satisfactorily the GAPI and OTIC performances. The *Outcomes* are accounted for primarily by the *Resources* used, followed by *Patents*, which are not dependent on resource levels. *Patents* thus appear as an exogenous variable, probably linked to the potential of each university, its size and geographical location. The entities that stand out in this regard are the GAPI IST, the OTIC UNL, the GAPI Aveiro, both the OTIC Coimbra and GAPI Coimbra, and the three integrated structures GAPI+OTIC. The variable *Studies* depend on the level of *Resources* of those institutions and are next in importance. Finally, to a lesser extent though still significant, *Marketing activities* have an influence on the *Outcomes*.

5. Concluding remarks

A cluster analysis was conducted to test the 1st hypothesis. In short, in line with institutional theory the assumption was that the diverse nature of institutions determined different behaviors. The cluster analysis produced an optimal result of eight clusters. Only two clusters had more than two elements, one of the with 7 entities (mostly GAPIs) and the other with 12 entities (11 of them were OTICs). The third cluster in terms of size has just 3 entities (being 2 of them integrated structures OTIC+GAPI). These results show how much the first hypothesis is plausible. By performing a discriminant analysis at the hypothetical initial clusters, i.e., a cluster of GAPI, a cluster of OTIC and a cluster of GAPI+OTIC integrated structures, it was found that the variables *Database* and *Spin-Offs* discriminate well these clusters and that only in 3 cases these two variables "failed" in the allocation to "natural" clusters. Both the cluster and the discriminant analyses results confirm therefore the assumption of the first hypothesis, that is, the institutional nature influences the behavior of the entities.

The 2nd hypothesis, in line with resource dependence theory, stated that the *Outcomes* were accounted for both i) the resources employed and ii) the activities pursued. The statistical analysis that was performed, and particularly the PLS estimation, point to the validity of a model in which the *Outcomes* depend i) on the *Resources* employed, ii) on *Patent* applications, iii) on *Studies* and iv) on *Activities*. In this model the *Patents* variable was removed from the *Outcomes* set, as indicated by factor analysis, and the *Training* variable was not excluded from the model. From these results it is possible to conclude, therefore, for the validity of the 2nd hypothesis, with the important qualification that the number of patents filed seems to be a relevant input to obtain the other Outcomes but they are not a result in themselves, rather they seem to be more an intermediate input. This condition is consistent with the views of Thursby & Thursby (2002) and Siegel et al. (2003) on technology transfer, referred to on section 3, in which, patent applications, together with the previous disclosure, are stages of technology transfer which are prior to licensing. Our research also confirms the validity of the theories of resource dependence in the process of technology transfer from universities (and other higher education institutions) to business firms, the importance of patents in technology transfer, as well as the relevance of two main dimensions of this process, the licensing contracts and the establishment of spin-off companies.

In this empirical study, other institutional aspects of the activity of GAPIs and OTICs, such as the public or private nature of universities and polytechnics where the GAPIs and OTICs are operating, or contextual factors such as the economic environment, were not analyzed. Beyond the consideration of these aspects, future studies should take into account the specific framework dimensions of TLOs and TTOs operating in the universities and their interaction with the regional innovation systems in which they operate. Further it will be critical to analyze further the universities to which these entities belong, namely the nature of their regional environment, their specialization, characteristics of the faculty, and volume of scientific activities.

The establishment of GAPIs and OTICs in Portuguese higher education institutions was connected to programs and funding by INPI and AdI, respectively the National Institute of Industrial Property and the Innovation Agency. The fact that (as highlighted in section 2) the learning curve is steep, with performance improvement occurring on a broad horizon, accrued to the fact that the breakeven point is usually reached on the medium term (5 to 7 years in the U.S.), suggests the need for sustained public funding, so that the positive results are expanded and consolidated. Further, the synergies and better results obtained through the combination of funding and the integration of downstream and upstream activities as it was made by some universities, through the joint GAPI+OTIC structures, would also be advisable in the future.

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Table 1- Surveyed entities

Entity	Hhigher Education Instution	Acronym
GAPI (TLO)	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 (TTO)	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

Table 2 – The variables of the study

Resources	1. Number of staff working in the unit 2. Existence of a database (dummy variable representing the existence or absence of a specialized IT system to support technology transfer)
Activities	3. Number of training activities promoted 4. Number of studies promoted 5. Number of networks or international associations in which the unit has been directly involved 6. Number of fairs, exhibitions or shows in which the unit was present in the previous 2 years
Outcomes	7. Number of patent applications in the previous 2 years 8. Number of technology transfer processes promoted by the unit in the previous 2 years 9. Number of licensing contracts of patented technology 10. Number of technology-based spin-off companies created out of the unit's activities

Table 3 – Factor Analysis - Summary of the statistics

Indicators	(threshold)	All Variables	Without Training	Without Patents	Without Train+Pats
KMO	>0,5	0,39	0,39	0,443	0,455
Bartlett	<0,05	0,011	0,001	0,047	0,006
% residuals >,05	<50%	58%	61%	53%	43%
GFI	>0,8	0,772	0,819	0,776	0,84
RMSR	<0,1	0,106	0,102	0,106	0,099

Table 4 – The four factors stemming from factor analysis

	Factors				Communalities
	1 "Technology Tranfer"	2 "Resources"	3 "Entrepreneurial activties"	4 "Marketing dimension"	
Staff size	,098	**,712**	,248	,175	**,609**
Database	,079	**,891**	,053	-,115	**,817**
Studies	,126	,273	**,720**	-,227	**,661**
Networks	,015	-,311	,409	**,669**	**,712**
Trade Fairs	,097	,195	-,145	**,826**	**,751**
TT_Processes	**,920**	,278	-,041	,095	**,933**
Lic_Contracts	**,877**	-,085	,384	,029	**,925**
Spin-Off	,131	,090	**,801**	,206	**,709**

Table 5 – Quality Indicators

	AVE	Composite Reliability	r^2
Studies	1	1	0,079
Marketing	0,604	0,748	0
Patents	1	1	0
Resources	0,731	0,844	0
Outcomes	0,574	0,798	0,39

Table 6 - Cross Loadings

	Resources	Studies	Marketing	Patents	Outcomes
Staff size	**0,864**	0,206	0,096	-0,335	0,281
Database	**0,846**	0,276	-0,165	-0,565	0,18
Studies	0,281	**1**	0	-0,149	0,411
Networks	-0,086	0,021	**0,891**	-0,01	0,251
Trade Fairs	0,067	-0,035	**0,643**	-0,018	0,149
Patents	-0,523	-0,149	-0,016	**1**	0,144

Tech. Transfer Contracts	0,337	0,164	0,109	-0,137	0,602
Licensing Contracts	0,115	0,309	0,171	0,019	**0,808**
Spin-off	0,21	0,391	0,268	0,264	**0,84**

Table 7 – Total Effects

	Studies	Marketing	Patents	Resources	Outcomes
Studies	0	0	0	0	**0,361**
Marketing	0	0	0	0	**0,287**
Patents	0	0	0	0	**0,409**
Outcomes	0	0	0	0	0

Chart 1 - Dendrogram using Ward Method

```
                         Rescaled Distance Cluster Combine

        C A S E          0         5        10        15        20        25
  Label             Num  +---------+---------+---------+---------+---------+

  GAPI Azores         2   -+
  GAPI Évora          5   -+
  GAPI Aveiro         6   -+-+
  GAPI Coimbra        4   -+ +---+
  GAPI+OTIC UTAD     25   -+ |   +---------+
  OTIC UNL           17   ---+   |         +----------------------------+
  GAPI Algarve        3   -------+         |                            |
  GAPI IST            1   -----------------+                            |
  OTIC ESB           10   -+-------------------+                        |
  OTIC Aveiro        22   -+                   |                        |
  OTIC IPT           12   -+---+               |                        |
  OTIC IPVC          23   -+   +---------+     +-----+                  |
  OTIC IPCB          18   -+   |         |     |     |                  +---+
  OTIC IPPg          21   -+---+         |     |     |                  |   |
  OTIC IPB           16   -+             |     |     |                  |   |
  GAPI UBI            7   -+             +-----+     |                  |   |
  OTIC UTL            8   -+---+         |           |                  |   |
  OTIC IPP           13   -+   |         |           |                  |   |
  OTIC UBI           15   -+   +-+       |           |                  |   |
  OTIC IP             9   -+   | +-------+           +------------------+   |
  OTIC Algarve       11   -----+ |                   |                      |
  OTIC Coimbra       19   -------+                   |                      |
  OTIC IPL           14   ---------------------------+                      |
  OTIC Lusíada       20   ---------------------------+                      |
  GAPI+OTIC Porto    26   -----------+-----------+                          |
  GAPI+OTIC Minho    27   -----------+           +--------------------------+
  OTIC Évora         24   -----------------------+
```

Chart 2 – Evolution of the distance between clusters and r^2, as the number of clusters grow (for Ward method)

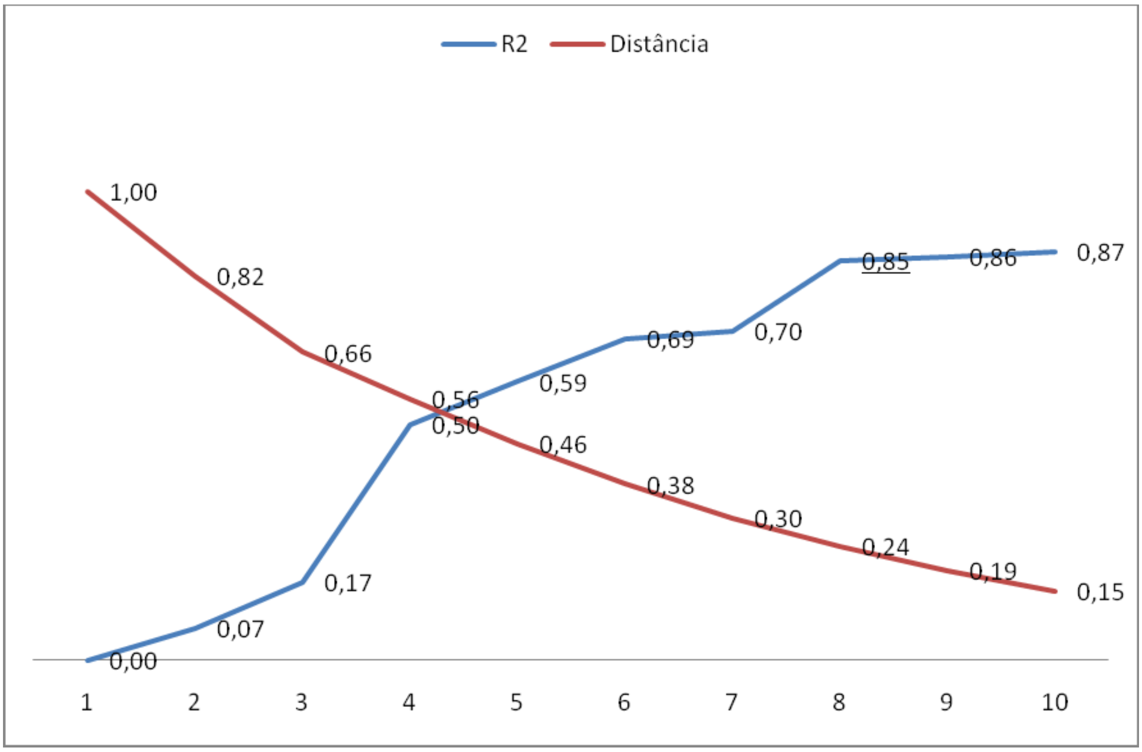


Chart 3 – Model derived from FA

Note: Resultados=Outcomes

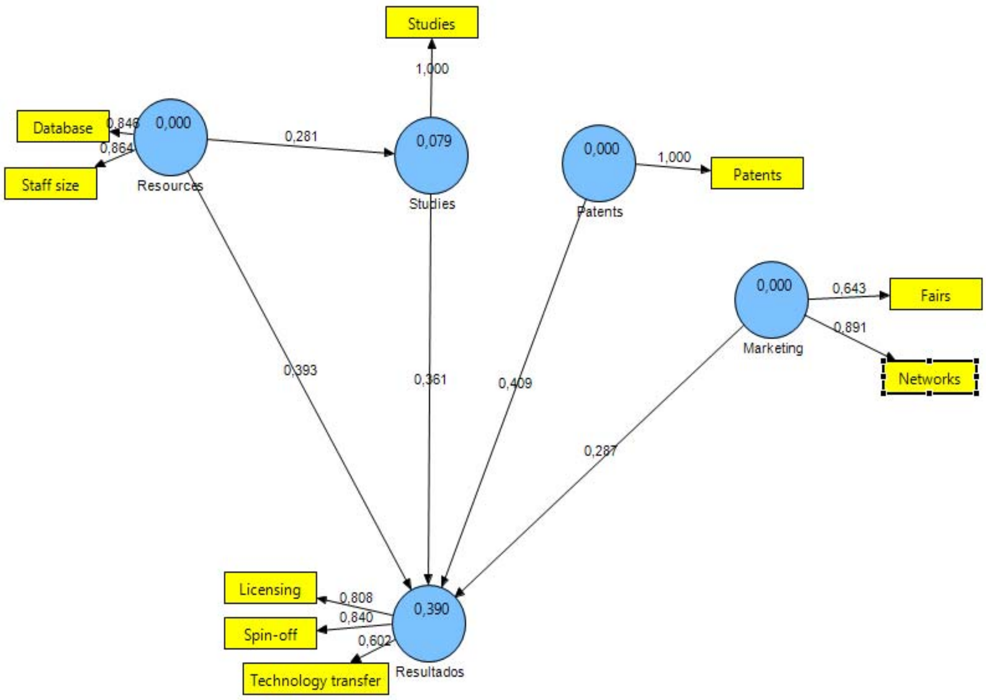
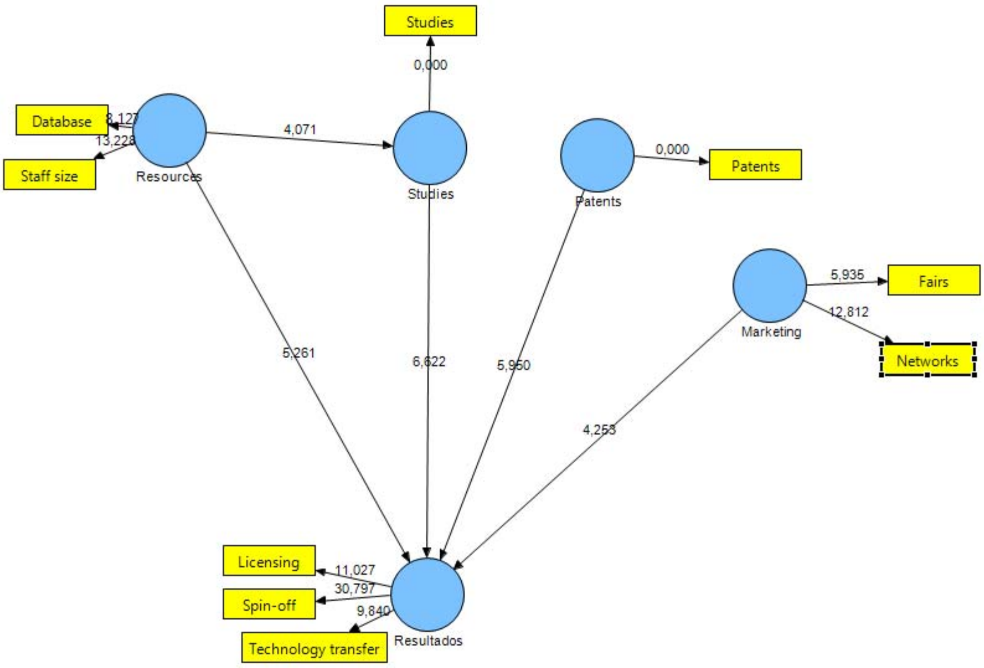


Chart 4 (t statistics)

Note: Resultados = Outcomes



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