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Connecting the Triple Helix space: actor-network creation and institutionalisation of knowledge transfer offices

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Abstract

Universities are central actors in scientific knowledge production. Public policies are emphasising knowledge transfer through a set of supporting mechanisms to promote innovation. One of these mechanisms is the establishment of innovation intermediaries. This article departs from an extended case study of an academic knowledge transfer office to highlight the institutional change in the Portuguese Triple Helix space, through the process of standardisation, the consolidation of specific professions and vocabularies, and the formalisation of boundary objects. This article departs from the actor-network theory as a research framework to illustrate tensions and contradictions in the institutionalisation of knowledge transfer. Social network analysis is used to map the evolution of the network and different centralities of actors, human and non-human, evidencing the relative importance of knowledge transfer channels. The institutionalisation of knowledge transfer is a continuous, unfinished, and precarious process that deserves attention from policy-makers.

Keywords: Knowledge transfer, Institutionalization, Actor-network theory, Social network analysis, University

JEL classification: O30, O39, Z13

Resumen

Las universidades son actores centrales en la producción del conocimiento científico. Las políticas públicas están enfatizando la transferencia del conocimiento para promover la innovación. Parte de este esfuerzo, es el establecimiento de intermediarios de innovación. Usamos el caso de una oficina de transferencia del conocimiento académico en Portugal para describir el cambio institucional en el Espacio de la Triple Hélice en ese país. Examinamos el cambio en términos de estandarización, consolidación de profesiones y vocabularios, y la formalización de objetos de frontera. Usando la Teoría Red-Actor como marco de investigación ilustramos las tensiones y contradicciones en la institucionalización de la transferencia del conocimiento. En adición, analizamos redes sociales para trazar la evolución de la red a medida que diferentes actores ocupan un rol central, alternado de esta manera la importancia relativa de varios canales de transferencia del conocimiento. La institucionalización de este proceso de transferencia es precaria pero continua y merece por tanto sostenida (Continued on next page)

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atención de parte del gobierno.

Palabras clave

Transferencia del conocimiento; Institucionalización; Teoría Red-Actor; Análisis de Red Social, Universidad.

Résumé

Les universités sont des acteurs centraux dans la production de la connaissance scientifique. Les politiques publiques mettent l'accent sur le transfert de connaissance à travers un ensemble de mécanismes d'appui en vue de la promotion de l'innovation. L'un de ces mécanismes est la mise en place des intermédiaires de l'innovation. Cet article part d'une étude de cas élargie d'un bureau académique de transfert de connaissance pour mettre en exergue le changement institutionnel dans l'espace de la Triple Hélice au Portugal, à travers le processus de normalisation, de consolidation de professions et de vocabulaires spécifiques, et la cristallisation des frontières. Il utilise comme cadre de recherche la théorie de l'Acteur-Réseau pour illustrer les tensions et les contradictions dans l'institutionnalisation du transfert de connaissance. L'analyse des réseaux sociaux est utilisée pour cartographier l'évolution du réseau et les différentes centralités des acteurs, humains ou non, mettant en évidence l'importance relative des canaux de transfert de connaissance. L'institutionnalisation du transfert de connaissance est un processus continu, inachevé et précaire qui ne retient pas l'attention des décideurs politiques.

Mots-clés

Transfert de connaissance—Institutionnalisation—Théorie de l'Acteur-Réseau—Analyse des réseaux sociaux—Université

Аннотация

Университеты являются центральными акторами в производстве научных знаний. Государственные стратегии придают особое значение трансферу знаний путем создания внедрения цепочки механизмов, продвигающих инновации. Одним из таких механизмов является формирование инновационных посредников. Настоящая статья начинается с детального рассмотрения деятельности академического офиса трансфера технологий в целях описания институциональных изменений в системе Тройной спирали Португалии через процессы стандартизации, утверждения специфических профессий и терминов, также формализации граничных объектов. Акторно-сетевая теория взята за основу для проведения исследования в данной статье, задачей которого является иллюстрация напряженностей и противоречий, возникающих при институционализации трансфера знаний. Акторно-сетевой анализ используется для создания карты эволюции сети и различных центров влияния акторов, людей и неодушевленных предметов, указывая на относительную важность каналов трансфера знаний. Институционализация трансфера знаний является непрерывным, бесконечным и случайным процессом, который должен учитываться управленцами.

Ключевые слова

Трансфер знаний, Институционализация, Акторно-сетевая теория, Анализ социальных сетей, Университет.

摘要

大学是科学知识生产的核心主体。公共政策通过一套促进创新的支持机制强调知识转移。这些机制之一是创新中介机构的建立。本文通过标准化过程、特定专业和词汇的整合以及边界对象的形式化,从学术知识转移办公室的一个扩展案例出发,着重研究在葡萄牙三螺旋空间的制度变化。基于作为研究框架的主体网络理论,说明在知识转移制度化方面的张力和矛盾。社会网络分析被用于确定网络进化演变和(人类/非人类)角色的不同中心,为证明知识转移渠道的相对重要性提供证据。值得政策制定者们注意的是:知识转移的制度化是一个持续的、需不断完善的和不稳定的过程。

关键词

知识转移; 制度化; 主体网络理论; 社会网络分析; 大学。

Resumo

As universidades são atores centrais na produção do conhecimento científico. As políticas públicas tem enfatizado a transferência de conhecimento através de um conjunto de mecanismos de apoio para promover a inovação. Um desses mecanismos é o estabelecimento de intermediários de inovação. Este artigo faz parte de um extenso estudo de caso de um escritório de transferência de conhecimentos acadêmicos o qual destaca a mudança institucional no Espaço da Hélice Tríplice em Portugal, por meio dos processos de padronização, consolidação de profissões e de vocabulários específicos e a formalização de objetos fronteirios. Este artigo utiliza a Teoria Ator-Rede para dar suporte à investigação de forma a ilustrar tensões e contradições na institucionalização da transferência de conhecimento. A Análise de Redes Sociais é usada para mapear a evolução da rede e as diferentes centralidades de atores, humanos e não-humanos, evidenciando a importância relativa dos canais de transferência de conhecimento. A institucionalização da transferência de conhecimento é um processo contínuo, inacabado e precário que merece atenção dos formuladores de políticas.

Palavras-chave

Transferência de conhecimento; Institucionalização; Teoria Ator-Rede; Análise de redes sociais; Universidade

Multilingual abstract

Please see Additional file 1 for translation of the abstract into Arabic.

Introduction

Triple Helix interactions are complex and include actors from different institutional spheres. The interrelation between overlapping domains of science-industry-government has brought attention to hybrid actors who are engaged in different spaces as innovation intermediaries. Knowledge transfer offices (KTOs)—a designation that encompasses the diversity of academic interface organisations in this study—are an example of this type of entity that tries to suppress the gap between ‘public science’ and business demand. In recent years, many universities have established KTOs as a consequence of the greater importance given to science commercialisation. These intermediaries play a specific role in the valorisation of research and knowledge produced within the university but often assume a broader role as animators of the regional

knowledge exchange dynamics. The implementation of KTOs is not only a consequence of the institutionalisation of knowledge transfer (KT) but is also a catalyst for the process.

The goal of this article is to illustrate the different phases and complexity of the institutionalisation of KT, in particular the university-industry linkages, and the relevance that the emergence of KTOs can have in this change. This research defines institutionalisation as an evolving process that produces new legitimacies, new formalised statutes, and resources that are reinterpreted and reconstructed by the actors. This paper uses the actor-network theory (ANT) and social network analysis (SNA) to present an extended case study of a Portuguese university KTO to underline its role in the translation of public and private actors' interests. The case studied is analogous to many other public Portuguese universities, where intermediation actors were initially informal entities based in programmes funded under the European CSF III (2000–2006), and formalised as parts of the structure of the Higher Education Institutions (HEIs), a cumulative process of professionalisation that is still ongoing.

The analysis develops a chronology of events providing an overview of the evolution and institutionalisation within the Portuguese Triple Helix (TH) system in the last decade. It explores the various phases of translation to transform a specific KTO into an obligatory point of passage, reaching the institutionalisation of actors, practices and routines. It is suggested that an approach mixing ANT and SNA helps to understand the creation and stabilisation of TH interactions and the evolution of the actor-network.

The article is organised as follows: Change and Institutionalisation of Knowledge Transfer presents some theoretical considerations about change and institutionalisation of KT, placing particular emphasis on the relevance of KTOs. Methodology underlines the usefulness of ANT and SNA as an approach to study institutional change, presenting the assumptions regarding the empirical studies. KTO Institutionalisation in Portugal presents the extended case study of a Portuguese KTO describing the stabilisation of the actor-network and the presentation of SNA. The article concludes with policy implications.

Change and institutionalisation of knowledge transfer

Institutionalisation of knowledge transfer

Change is often characterised in a simplistic way, distinguished as incremental or abrupt, where the results are continuity or discontinuity. Institutional analysis has struggled to understand the processes of change because it often treats institutions as rigid elements with a binary character. This means that certain institutional arrangements are envisaged as being present or absent (Tolbert and Zucker 1996).

An approach based on the assumption of this binary character is limited to the understanding of institutionalisation as a process that occurs in a continuum and not crystallising from one moment to another. This means that: '(...) there is room to study partial and incomplete processes of institutionalization with the expectation that different levels of the variable will have disparate implications for the performance of whatever phenomena one examines. More succinctly, institutionalization is a matter of degree' (Owen-Smith 2011: 68).

Institutionalisation is thus a complex process that can be analysed from the combination of two central aspects: habituation and legitimisation (Berger and Luckman 1999).

Habituation is a central element of social reproduction, making interaction more standardised and more predictable to actors. It results from the frequency of certain actions that can shape a pattern and can be initiated with less effort. Certain actions are transformed into habits, retaining and integrating meanings as routines, becoming relevant elements of collective understanding and organisational memory.

As the classic text of Berger and Luckman states (1999: 66), institutionalisation occurs whenever there is a reciprocal typification, available to all players, evolving from pre-existing frameworks of thought and action. Legitimacy refers to the process of deepening crystallisation of how things should be done, the development of causal imaginaries, emergence of different bodies of knowledge, and ultimately, the creation of a symbolic universe, with beliefs and practices imbued with normative meanings. Legitimacy is a generalised perception or assumption that certain actions are appropriate and even desirable in a given social system (Suchman 1995). Legitimacy is ensured by the existence of self-reproducing processes that turn actions into habits and practices with a shared meaning.

Colyvas and Powell (2006) analysed, with these assumptions, the institutionalisation of the university-industry linkages in the USA, using a case study of Stanford University. After chronologically reviewing the process of institutional change in KT, these authors delimited a series of stages on the way to institutionalisation. The first phase was called idiosyncratic, when transfer relations still happen sporadically. The second is the standardised phase, when rules and routines are already matured and coded, in particular with the support of formal structures like the KTOs. Finally, in the institutionalised phase, commercialisation of science self-replicates is already accepted by the majority of actors and is protected against its antagonists.

To sum up, KT institutionalisation produces new legitimacies, new formalised statutes, resources that are reinterpreted and reconstructed. Institutionalisation cannot be understood as completely driven by exogenous forces. The process cannot be assumed as an attribute that is present or not, or which arises spontaneously and automatically. The legitimacy and habituation are reinforced, but do not always move at the same pace, generating diverse institutionalisation processes. Full institutionalisation requires that it be accepted and internalised by the actors creating a new set of practices, routines, vocabularies and organisational fields. It is relevant that the analysis of real case studies pays attention to unfinished, diverse and ambiguous processes of institutionalisation.

KTOs as translators within the Triple Helix

The Triple Helix (TH) is commonly interpreted as an innovative and an entrepreneurial ecosystem with components (actors and institutions), relationships (linkages) and functions (Nyman 2015) from different institutional spheres (Etzkowitz 2008). But the TH framework can be expanded using the notion of TH space, in which the institutional spheres of university, government and industry interact and co-evolve overtime (Etzkowitz and Ranga 2010).

One of the TH spaces is the 'consensus space', the physical and virtual space where actors interact, come together, formulate strategies and embrace common objectives and projects. The consensus space is '(...) a mix of top-down and bottom up processes to create leadership through collaboration rather than diktat, a neutral ground where

the different actors in a region, from different organisational backgrounds and perspectives, can come together to generate and gain support for new ideas promoting economic and social development' (ibid: 17-18).

Public policy is crucial in forging meaningful university-industry relations, but it is difficult for governments to directly stimulate innovation and cooperation because these linkages depend on mutual interest, trust and comprehension (Bychkova et al 2015). Public incentives for the generation of innovative and entrepreneurial ecosystems include stimulating the creation of intermediaries to act as brokers in the innovation process between different institutional spheres, to reduce transaction costs (Technopolis 2015) and to surpass their own limitations of distance to localised actors (Fuerlinger et al 2015).

Several types of hybrid organisations have emerged in the areas where institutional spheres overlap, functioning as intermediary actors: technology centres, approval and testing laboratories, technology parks, science parks, research support services, innovation centres, technology platforms, patent offices, business incubators and KTOs. These organisations have specific functions but also have systemic value by fostering connectivity and by creating points of contact among the different institutional spheres (Howells 2006). Intermediary actors stimulate the emergence of 'boundary objects' (Gieryn 1983; Gieryn 1999), which are social artefacts that lie between the boundaries of different social worlds allowing for a more effective communication between groups with divergent perspectives (Star 1989). Boundary objects have sometimes been associated with non-human actors with agency from the perspective of the ANT (Fleischmann 2006). As examples, competition of ideas, incubation services, business plans and patents are evident boundary objects commonly used in the connection between the worlds of science and industry.

Some authors, such as Marques (2016), have underlined that business planning and promotion of competition of ideas have functioned as boundary objects with a relevant impact in the number of "traditional" science commercialisation outputs, such as registered patents, but were simultaneously a means for changing the entrepreneurial culture in the academy. Other boundary objects offered by KTOs, such as business incubation and the S&T infrastructures, are important for innovation dynamics (Amaral 2015). Services from intermediaries, predominantly based on informal relationships, can be actively employed to overcome weaknesses in TH interactions (Todeva 2013).

The emergence of these new types of organisations is a clear trace of institutionalisation. In this regard Etzkowitz et al (2000: 316) added that '[t]he entrepreneurial university requires an enhanced capability for intelligence, monitoring and negotiation with other institutional spheres, especially industry and government. Beyond the ability of the top leadership of the university to engage with their counterparts in other institutional spheres, a mid level organisational linkage capability gives the university the ability to identify confluence of interest between external organisations and their academic counterparts. Interface specialists make introductions, organise discussions, negotiate contracts, and otherwise act in an intermediary role to facilitate interactions with their counterparts and other potential partners in government and in industry. Interface specialists emanating from various organisations and institutional spheres forge a common identity, independent of their employers. This is expressed organisationally in the creation of organisations representing the emerging interface professions'.

Universities of all types and sizes have maintained and developed these intermediation actors (Greenbaum and Scott 2010). KTOs focus primarily on science commercialisation from their host university, supporting the goals of the administration, but also supporting stakeholders working in different TH institutional spheres, such as the scientists and the decision-makers (Jensen et al. 2003). Beneficiaries of KTOs have different organisational cultures (Siegel et al. 2003).

This broad range of stakeholders makes the role of KTOs more ambiguous, thus making it difficult to define their actions respecting both the necessary focus on private revenues of commercialisation and public access to research results (Owen-Smith 2011). This ambiguity is present in the jargon that professionals develop as KTOs are institutionalised. The language of KTOs is a mixing mechanism for different types of vocabularies: legal vocabulary (which emphasises the contractual obligations related to industrial property rights and contracted research), technical (which focuses on scientific discussion, technology artefacts and KT), academic (which underlines the university's inventions as extensions of the roles of education and research and the concerns of public access and conflicts of interest), relational (a more diffuse category that emphasises issues of mutual interest and trust, essential to long-term relationships between academia and businesses).

KTOs have been studied in the last years but a deep understanding of the role of intermediaries within the TH still requires more research (Havas 2015). This study intends to contribute to the clarification of the institutionalisation of KT practices and the role that KTOs play both as a result and as a catalyst of the process.

Methodology

ANT as a framework for knowledge transfer institutionalisation

ANT provides a framework in this research for the historical analysis of transformation practices in Portugal. ANT enables understanding change and institutionalisation. ANT is a conceptual tool that has its origins in the Social Studies of Science and Technology (classic examples can be found in Callon 1999, 1986; Latour 1987; Latour 1999, 1983; Latour 1999, 1986; Latour 2005; Law 1986a; Law 1986b). Understanding ANT as a theory is often criticised, but it is certainly a useful approach for complex objects.

ANT directly relates actors at the micro-analytical level with the formation of a macro-actor, defined as the actor-network. The social structure is not static, but rather a place under construction, in tension, generating relational and reproductive effects (Law 1992). This approach assumes that actors have meaning only when embedded in a network of relationships. Thus one '(...) actor-network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of' (Callon 1987: 93).

The actor-network is a system of alliances that are constantly changing, involving a range of actors, and necessarily including human and non-human elements. An actor-network is unstable over time and is maintained continuously through active efforts; otherwise it will fail and dissolve.

The notion of translation is probably the most important in ANT. It involves the transfer and displacement of interests, purposes, devices, and inscriptions. As Callon (1999, 1986: 81) states: '(...) to translate is also to express in one's own language what others say and want, why they act in the way they do and how they associate with each

other: it is to establish oneself as the spokesman. At the end of the process, if it is successful only voices speaking in unison will be heard’.

At the beginning of a process of translation, different collectives are separated, without communication, but in the end there are speeches about shared objectives and joint activities. In this process, certain facts and artefacts, previously controversial and contingent, are taken as opaque and non-problematic elements that no longer need to be discussed or be subject to the scrutiny of stakeholders. They are assumed to be valid, certain and always available, becoming a base for individual and collective action. Translation consists of four phases that can only be understood as overlapping moments in a continuous process with multiple voltages and not as clearly defined moments that together give rise to a final moment. It is a precarious process of stabilising the relational order. These four stages are summarised in Table 1.

The translation process, leading to the formation of an actor-network, can be interpreted as a process of institutional change, not exogenously defined, but seen from the inside. Translation between different actors builds into the institutionalisation of KT by creating habituation and legitimacy of new actors, vocabularies and activities, including boundary objects between different collectives. Institutionalisation arises as a result of the interaction and translation among different actors, human and non-human, who pursue common interests, ‘(...) ordered networks of heterogeneous materials whose resistance has been overcome’ (Law 1992: 380). The actor-network stabilisation resembles institutionalisation because ‘(...) institutionalization is both a material matter and a question of arranging and ordering those materials’ (Donnelly 2010: 303). In a different disciplinary tradition, as suggested by several authors (e.g. Berman 2008 and Owen-Smith 2011), the notions used in ANT can contribute to the institutionalism rationale, by calling attention to temporary stabilisations and facilitating the analysis of change.

Methodologically, ANT is applied by following and interpreting the actors, primarily by identifying associations using interviews, by ethnographic research and by analysing inscriptions. This fieldwork, resulting in extensive participant observation, was carried out

Table 1 The four phases of translation

Phase	Synthetic description
Problematization	It is characterised by an actor that defines a problem. By revealing the problem to others and how it can be overcome, this actor is trying to put forward an idea and become indispensable, an obligatory point of passage to reach the solution of the identified problem. The starting actor is transformed into a ‘translation enabler’. The beginning of the process for collective engagement may or may not be successful to build the network, and will depend on the arguments, disputes and consensus shared among the various actors in the particular definition of the problem and its solution.
Interessement	The ‘translation enabler’ convinces other actors that the problem is also relevant to them and recruits them to assume various roles in the network. They recognise the centrality of the (initial) actor regarding the problem and its resolution. Trials of strength will determine how actors accept the initial vision of the translation enabler or if those involved resist and define divergent objectives, interests and motivations.
Enrolment	Actors define and detail acceptance by developing a specific role in the network. This is a period when multilateral negotiations will lead to the success of the definition of the obligatory point of passage. Through a variety of mechanisms, devices and strategies that may involve the simple request to the use of coercion, enrolment will consolidate the roles of actors, resulting in a system committed to a shared goal.
Mobilisation	The acceptance of the obligatory points of passage is achieved by stabilising the actor-network. The ‘translation enabler’ is assumed to be the spokesperson of a relatively passive network of actors.

Source: own elaboration

on the premises of a KTO located in a public university in the Portuguese region of Algarve (University of Algarve). This intermediary actor is called KTO1. Such a method motivated a deeper understanding of the context in which KTO1 was inserted and also how the change occurred during the period of fieldwork. The KTO is seen as a bridge of the academic knowledge to the TH space. The immersion of the researcher in KTO1's daily routine secured privileged access to internal documents such as project applications, meeting minutes, strategic action plans and digital information. The fieldwork took place between 2008 and 2011. The information collected during fieldwork was supplemented by 32 semi-structured interviews with various kinds of KT stakeholders (Table 2).

Interviews were collected until the point of saturation, in which only redundant information came from new interviewees (Mason 2010). For an in-depth case study like this, it is considered essential, as Stake (1995) suggests, to understand the meaning of the interviews and not to focus excessively on partial transcripts of the interviews that can easily be de-contextualised. Content analysis (Hsieh and Shannon 2005) was used to create a typology of modalities of university-industry interaction, which were acknowledged as boundary objects in the study.

SNA as a tool to map structural characteristics of the TH spaces

SNA is used in a complementary way to ANT, as a formalised method, to map actors, centralities and types of relationships in crucial moments of the consolidation of this actor-network as a macro-actor in KT. In the last years, SNA has emerged as a fruitful tool to examine the involvement of actors within a given system (for a review see Lemieux and Ouimet 2004; Rivera et al 2010) and to map their inter-organisational

Table 2 Interviews: types of stakeholders and objectives

Type of stakeholder	Objectives of the interviews	Number of interviews	
University	Management of the university	Understand the perspective of the university board (rectory) in relation to the mission of the university and knowledge transfer activities. Assess their perspective regarding the evolution of KTO1.	2
	Faculty/departments	Understanding the relationship of KTO1 with Professors and teaching staff and the linkages of KT with traditional functions of the university.	3
	R&D units	Check the uses that researchers make of KTO1 and the importance they give to knowledge transfer.	9
Industry	Spin-offs and start-ups	Realise the ambition of entrepreneurs and the role that KTO1 and 'boundary objects' played for launching the companies.	6
	Enterprise associations	Identify collaborative networks with firms and understand the role of KTO1 in the context of Triple Helix relations within the region.	3
Governance	Regional and national bodies	Identify collaborative networks with governance actors and understand the role of KTO1 in the context of Triple Helix relations within the region.	4
Hybrid	KTO technical staff	Understanding work processes, leadership and power, goals, available resources. Compare KTO1 with different types of intermediary actors in the implementation of its activities. Detail the specific evolution of KTO1.	5

Source: own elaboration

linkages (Ter Wal and Boschma 2009). SNA can be particularly interesting to understand and measure relational capital within a specific innovation ecosystem (Russell et al 2015).

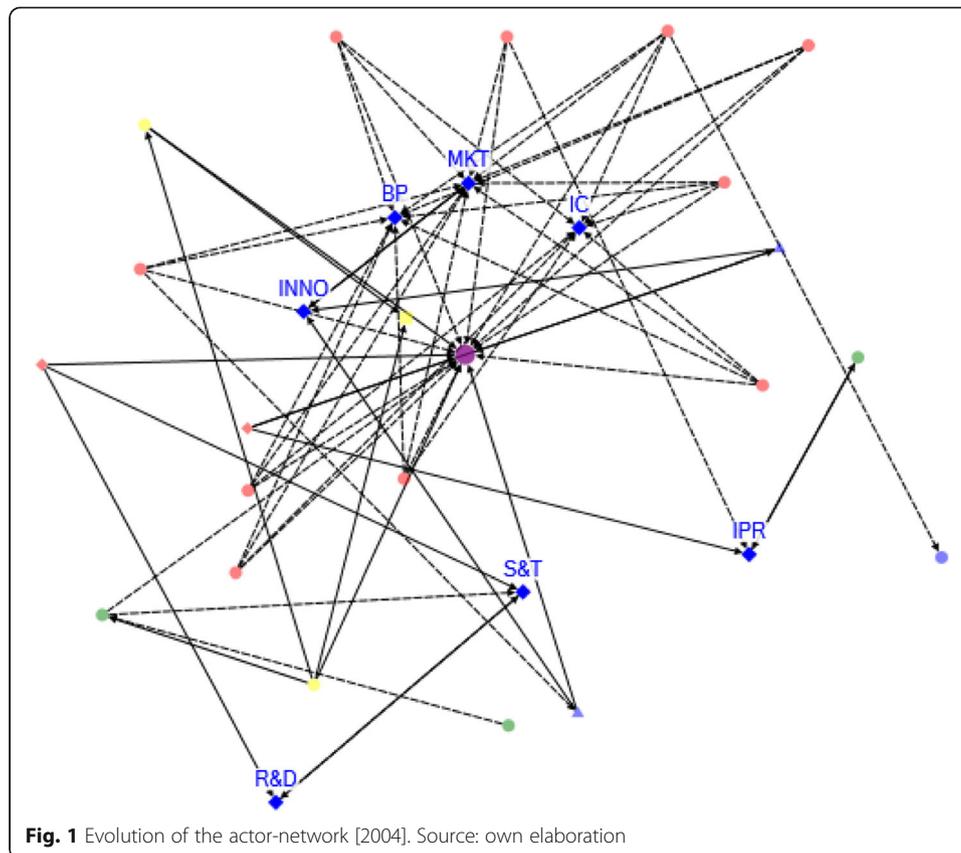
SNA takes as its starting point the notion that KTO1 is the central node of the network. This SNA points to what is designated as an egocentric network in the literature (Marsden 2002), mapping the relations around a focal agent—the *ego*. This understanding is highly connected to the ANT assumption of obligatory points of passage in the TH relations in its context of action. The central actor is KTO1, and the centralities of the other actors have a relative understanding to the office as an obligatory point of passage.

A SNA is an exploratory process for connecting actors and visualising specific dimensions (Bonsignore et al 2009). The process is dynamic and non-linear, depending largely on contextual factors such as the network size and the complexity of attributes. To give meaning to the graphical analysis, each node should be visible, directionality and intensity of each linkage must be noticeable and clusters and outliers must be identifiable. Attributes that exist on each node should be clearly defined, corresponding to the various shapes, sizes and colours. The software used was NODE XL for Excel 2007 (Smith et al 2010). For a review of this software see Smith et al (2009).

The basic information for the SNA was based on the available data from the information system of KTO1. This system included all the fulfilled 'contact forms' by the KTO1. Contact forms included diverse information such as organisational details, type of support requested from the KTO1 and subsequent actions implemented by the staff. This data facilitated the identification of the modality of interaction in each contact. It was supplemented with information gathered from the interviews and the documental analysis of additional corporate information available (mainly from the official websites), to allow for elaboration of the relational matrix. In this way, this matrix includes all initiatives supported by KTO1, since its creation in 2003 until December 2009. It is nonetheless relevant to acknowledge that the relational data prior to 2008 is based on relatively old retrospective information that may have limitations in terms of accuracy.

The linkages refer to the connections between the KTO1 and other organisations that were reported in the contact forms. Data regarding the linkages of remaining actors was supplemented by direct information gathered in the interviews. The nodes represented have the following interpretation in the relational figures (Figs. 1, 2 and 3). KTO1 is represented by the central purple circle. The red nodes are actors from the business side, such as start-ups and spin-offs (circles) and existing companies (diamonds). The yellow nodes are business support entities (squares) and business associations (circles). The orange nodes are private financing organisations (squares) and public financing organisations (circles). The green nodes are national (squares) and regional (circles) governance actors. Finally, blue nodes represent HEIs related actors: departments, faculties and schools (squares), R&D units (triangles), other KTOs (circles) and UTEN network of offices (larger triangle). The network also presents the modalities of interaction, interpreted as boundary objects, represented by blue diamonds, that connect actors with the KTO1: market, ideas competition, business plan, S&T infrastructures, innovation, R&D and IPR.

Market (**MKT**) identifies the set of interventions mentioned especially in the case of entrepreneurs approaching potential customers and to answer to the bureaucratic authorisation processes of the activity. The idea competition (**IC**) refers to the



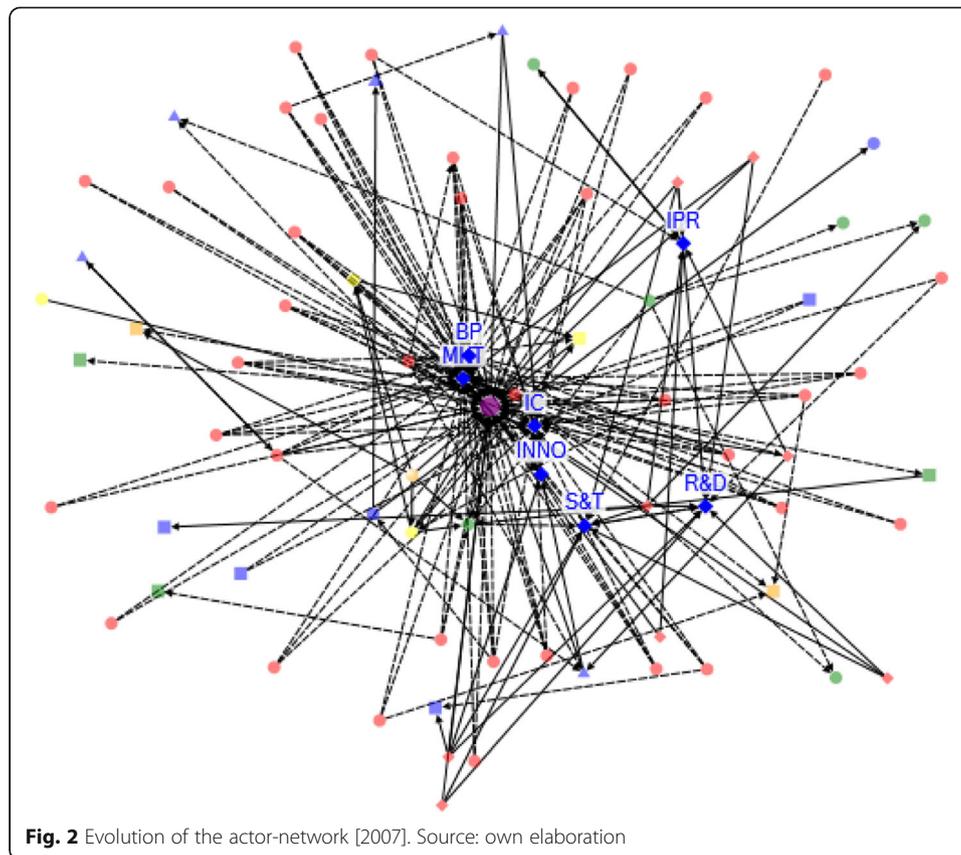
boundary object that fostered business generation and new spin-offs from the academy by means of a contest. The business plan (**BP**) refers to the support in the construction of a formal document structuring the business idea. The boundary object designated as **S&T** refers to collaboration, management and provision of scientific-technological and incubation infrastructures. **INNO** refers to activities directly connected to the development of new products and processes. **R&D** relates to support in the preparation of collaborative R&D projects. **IPR** relates to interventions at the level of industrial property rights, in particular with the registration and licensing of patents. It is worth noting that the relationships are directional, represented by the arrows at the end of each connection, and the density ratio is also represented by solid or dashed lines.

KTO institutionalisation in Portugal

Steps towards the stabilisation of a KTO actor-network

Problematization (199...–2003)

The chronology of events begins when JW, the president of the regional authority and a full professor at the university, decided to propose a project aimed at instigating regional development based on innovation. This particular region had common problems in Portugal that are quite usual all over Europe: lack of technological intensity and innovation in business and a very limited degree of interaction between the skills that the university had developed and the implementation of new products and processes that could have economic value and innovative potential.

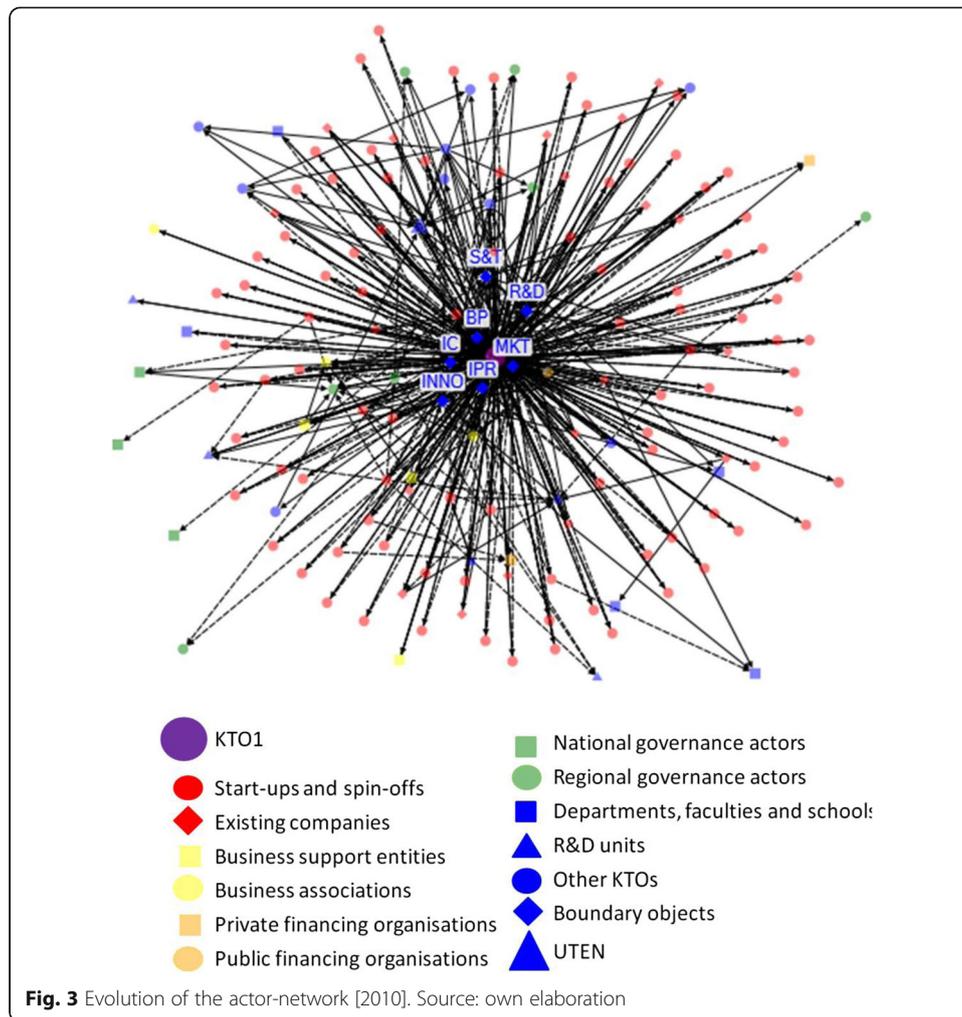


This problematisation was essentially related with the academic research of this individual. He occupied an intermediary position between the world of planning and governance and the university, giving him a unique perspective to engage with these two collectives. JW intended to create an entity that could be considered a centre of innovation capable of (through formal mechanisms such as industrial property) coordinating activities and developing innovative tools for innovation in collaboration. This centre would be able to talk with firms and university research groups, business incubation centres, industry associations and the regional governance bodies (CCDR Algarve 2001). According to the interview with JW, the centre should assume a pivotal role of linking science to the market, which was neglected due to the lack of intermediation actors within the region. The centre would become an obligatory point of passage in the region for the implementation of innovative projects.

In 2002, an opportunity appeared to finance a project with these characteristics through the ERDF Regional Programme of Innovative Actions. Thus, the regional authority decided to proceed with an application for this funding opportunity. The project submitted encompassed several sub-actions related to the valorisation of knowledge. The main action, listed first, was the establishment of a regional centre for innovation.

Interessement (2002–2005)

The application was approved by the European Commission, and it was necessary to define a concrete work plan involving, since its inception, private actors, including a regional enterprise association and an association of business support. JW tried to increase the interest of other actors regarding the problem involving the university.



The regional authority was involved in the proposal as the main proponent. The interest in participating in the project was related both to the particular topic and to the possibility of securing additional funding for daily tasks.

The initial strategy for the centre defined the modalities of integration of other partners, the project monitoring and the promotion of their results (CRIA 2002). The centre was established with the purpose of creating a platform for connecting innovation actors, including the university, technological centres and firms in the region, enabling the incorporation of research results into the productive processes, generating more value through the regional economy.

Thus, the centre focused on five main areas of activity. Firstly, a culture of innovation was created within the university and economic ties were generated by fostering cooperation channels between the various actors. Secondly, technology-based companies were promoted by stimulating the creation of new spin-offs, the dissemination of best-practices of successful companies and the qualification of the existing economic structure. Thirdly, another dimension considered was the animation of a network of partners in the region to install one scientific-technological infrastructure with incubation areas. Fourthly, a group of activities would pay attention to the organisation of procedures for innovation and patenting. Finally, the last dimension was participation

in national and European networks in the areas of innovation and KT, promoting co-operation and exchange of good practices.

To verify the complexity of the actor-network creation, we present the SNA results. The figures drawn can be interpreted as static photographs, in 2004, 2007 and 2010, of the actor-network formed around KTO1, mapping the set of relations and proximities between this office and a series of actors and boundary objects that came together.

Figure 1 shows the network and the weight that firms have in the total number of relations with KTO1. Specifically, some boundary objects are more central than others. The most central are those connected to modalities of interaction related to academic entrepreneurship.

Enrolment (2003–2007)

The partners involved in the innovation centre would function in accordance with the objectives of the approved project. The regional authority would guarantee the payment of expenses related to the acquisition of services, organisation of meetings and production of publications. The university would be responsible for hiring the technical staff for the team, providing facilities and equipment on campus for its operation. The association of business support would promote encouragement of entrepreneurial projects in strategic areas by mobilising young entrepreneurs. The business association would develop activities to promote innovative businesses, namely, disseminating good-practices.

The actors involved launched their activities. The total project budget for 10 months between May 2003 and February 2004 exceeded a half million Euros. The project included an office located in the university campus, which began to develop its activities with a technical team with university members and regional authority. Being located on the university campus promoted the connection between university research and the companies to clearly take over as the main objective of the centre. JW ensured that he assumed the leading role in the strategic guidance of the initiative.

Given its physical location, the centre was assumed to be an obligatory point of passage for the actors already engaged in KT boundary activities, such as the promotion of intellectual property rights, the preparation of applications for collaborative R&D and the applications for financing infrastructures for science and technology. An idea competition in the university was released. Of 40 competing projects, 12 winners were awarded with a professional business plan. In parallel, the centre attracted to the university the installation of GAPI (units for industrial property rights promotion), sponsored by the Portuguese National Institute for Industrial Property (INPI), stimulating synergies between the two work teams.

In September 2004, the project that framed the activity of the centre came to an end. The assessment of the project (CCDR Algarve 2006) emphasised how this centre was relevant to establishing the creation of a regional innovation system, allowing the university to expand abroad, especially to the business community. The assessment also noted that the regional community was becoming sensitised to the implementation of projects in collaboration with companies and research groups. In the view of the evaluators, the project was thus taking the first steps to '(...) structure an interface entity between the university and the business community' (ibid: 34), that could consolidate itself as a stable platform among the different actors in the relationship between 'public science' and the market. In a planned manner, it was the university who capitalised on the success of the project internalising the continuation of the centre.

The search for legitimacy at the end of the project and the need to continue the activities of the centre were accepted by all partners. At this point, without human resources associated with the centre, the university initiated the hiring of young graduates in Economics through three internships. These trainees supported the winners from the idea competition to help implement their business plans. At the same time, the centre benefited from the everyday presence of the GAPI technicians and an experienced consultant—at the time the coordinator of the association of business support, a partner in the project of Innovative Actions Programme. He was contracted to help the development of one S&T park project of the university. This consultant gradually assumed a leadership role in the team and ended up making a full transition, abandoning his previous position and informally embracing the new position at the university as coordinator of the centre. In parallel, other human resources came to the centre; the first was a business manager under an unemployment programme; the second was an internship to conduct a research study on collaborative networks of the university.

At this time, an opinion emerged in the university that continued until the end of the fieldwork: the number of staff in this office was too high for the needs of the university. This illustrates that KT was not yet legitimate. Faced with the possibility of having to abandon this function at the university, the rector began searching for funding to support the activity of KT.

The growing complexity of the network is illustrated by Fig. 2. Firms played a prominent role in the network, and boundary objects linked to entrepreneurship continued to gain importance.

Mobilisation (2006–2010)

In early 2006, the required projects arose under national programmes that directly supported KT activities. The approved financing from the NEOTEC programme focused on fostering technology-based entrepreneurship and enrolled the partnership of the initial Innovative Actions project. A second project, approved by the OTIC programme (offices for technology transfer and innovation), also resulted in securing additional funding for activities of university-industry cooperation. These programmes, in addition to the funding for the installation of GAPI by INPI created for the first time in Portuguese universities conditions to establish KTOs across the majority of HEIs in Portugal.

In mid-2006, a European cooperation project was approved by the centre. Among other activities, it aimed at the preparation of a regional innovation plan and a catalogue of skills and services of the university, which was prepared in close collaboration with the regional authority and the hiring of four specialists. These additional human resources endowed the centre with greater experience and scientific expertise. In early 2006, what would be the core of the KTO1 team for the next couple of years was formed. This staff comprised a group with its own distinct vocabulary mixing the language of firms and research, becoming another cornerstone in the institutionalisation process.

Simultaneously, a very important change happened. JW, the main instigator of the centre, assumed the role of rector of the university, focusing on the importance of TH interactions to develop a more engaged university. With this change, the main 'translation enabler' assumed a more distant role with the everyday activity of the centre but helped to ensure a 'formalised' legitimacy to these activities and for KTO1.

The centre began to focus increasingly on academic entrepreneurship support, mainly driven by the higher vocation and experience of the technical team, coming

mainly from economics and management sciences and in particular from the coordinator, recognised regionally for being a young entrepreneur. R&D collaborative projects and licensing of IPRs were more difficult to stimulate due to some distance from the internal stakeholders at the university, the lack of scientific expertise of the team and the limited absorption capacity of regional firms. Work processes remained confusing and non-standardised, unless exogenously demanded, as in the case of IPR activities where GAPI had to meet certain formal external procedures.

In 2007, KTO1 hosted a new initiative, a thematic platform that sought to promote a consistent and a coordinated provision of advanced services to the Golf industry. A KT officer was hired in early 2007 but this platform was built slowly and with no results, stimulated mainly by the enterprise demands. In 2007, INPI decided to equip GAPIs with more competences in the promotion of protected knowledge. A third element was added to the GAPI. This new function was quickly abandoned due to the university's scarcity of public funds, with the INPI also discontinuing support at the end of the same year. In 2007, the office also performed a new idea competition, resulting in about seventy applications from which 15 winners were selected. KTO1 developed at this stage the first substantial efforts aimed at connecting existing firms with existing university research areas with the organisation of university-industry meetings. Legitimacy was high and habituation was growing among the internal and external stakeholders of KTO1.

Despite some success, the KTO1 then began a tortuous phase where the absence of a structured commitment from the management of the university caused a rotation of technical staff, and the coordinator admitting it was undergoing the phasing-out stage. 2008 was a year of staff reduction, with many people leaving the office due to lack of finances and due to the precariousness of working conditions (mainly short-term contracts). The actor-network around the KTO1 was about to blur. The strategy to save the office, orphaned at this stage with no structured initiative by the management of the university, was to give greater attention to the provision studies and to promote applications for European Union initiatives, particularly European Cooperation Programmes.

At the same time, UTEN (University Technology Network) Portugal was launched. This was an initiative which stemmed from an agreement between the Portuguese government and US universities, for learning science commercialisation practices, towards the professionalisation of technical staff in Portuguese KTOs. The main North-American organisation in UTEN initiative was the University of Texas at Austin. The initiative began in 2008 with a series of visits to the Portuguese universities, including KTO1, to verify research and transfer potential.

The strategy adopted by the office with the submission of applications for European projects was successful with a very wide range of projects being approved. This was a detour in the translation process that continued for a new stabilisation after ensuring the capacity to financially sustain KTO1. These projects were funded by different sources, with a preponderance for the various sub-initiatives of the European Cooperation Programme INTERREG. Approved projects focused on benchmarking and mainstreaming of business innovation, innovation policies, management of IPR, scientific and technological infrastructures, among other topics directly connected to KT traditional activities. These projects were also important in the standardisation of practices and formal procedures, in particular, supporting entrepreneurship and collaborative R&D projects. The standardisation of practices, for example, with the creation of guidelines,

which were defined within the projects' activities, is usually indicated as another central element in KT institutionalisation.

More than a dozen projects had an impact in the office, but not all were positive. On the one hand, the projects created financial relief that ensured the continuation of KTO1. On the other hand, the technical team almost doubled in size, reaching around 15 elements (up to a maximum of 19 staff members). This fluctuation of the technical staff was not positive for KTO1 dynamics since the necessary competencies were mainly tacit and not formally developed in education. Much of the staff know-how came from accumulated experience.

In late 2009, the office co-organised an event between entrepreneurs and researchers, and one of the issues raised was the need to formalise KTO1, giving stability to human resources and a place in the functional structure of the university (Pinto 2013).

In 2010, the network was greater than ever in terms of nodes and relations (Fig. 3). The most central boundary object was MKT followed by a set of five nodes connected to 'public science' and then a specific firm. The BP, a regional governance actor, and the idea competition (IC) were other relevant actors, showing that all kinds of TH interactions were present in the stabilisation of the actor-network. This inference can be confirmed by the analysis of betweenness metrics for each node (Appendix).

In 2010, this last important change materialised. As a result of the change proposed by the Legislation Framework of Portuguese Higher Education Institutions (RJIES—Regime Jurídico das Instituições de Ensino Superior, Law 62/2007 of 10 September), the university changed its internal structure creating a unit to support scientific research and postgraduate training. This unit consisted of three divisions; one of them being a division to encourage entrepreneurship and technology transfer.

This last division absorbed KTO1. Throughout this process of internal re-organisation, the participation of the staff in the office was not considered. JW abandoned the role of being directly hierarchically responsible for KTO1; a role that was assumed by a vice-rector. The goal of the management of the university with this new division was to retake the strategic lines drafted in 2004, establishing a way to look primarily inside the university to connect with the outside environment. The office was transformed to a formal division of the university.

The participation of three elements of the KTO1 in the UTEN internship programmes also emphasised the need for standardisation of the transfer process. Models, forms, procedures and software tools to support the process in the foreign institutions visited were analysed and were presented by the trainees but were not applied. Nevertheless, the financial capacity to materialise these efforts did not exist. Such ambition was still only an intention, since there was no permanent technical staff at KTO1, and all human resources were paid via short-term projects and were not part of the permanent structure of the university by the middle of 2011.

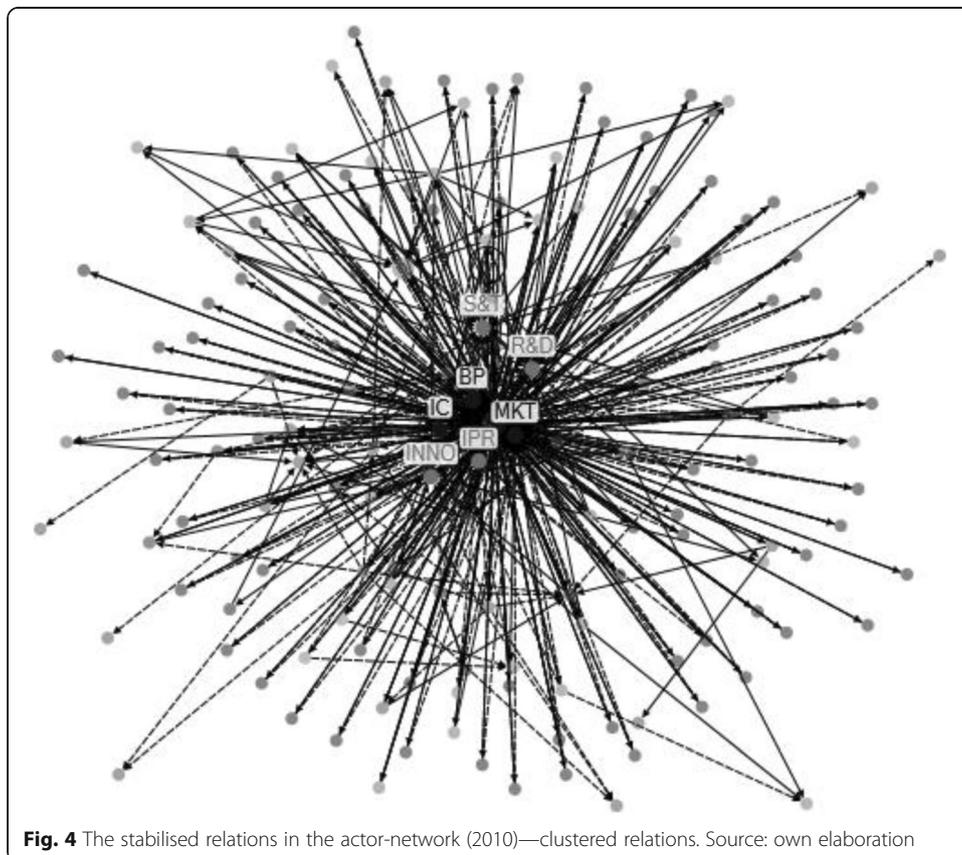
KTO1 is an obligatory point of passage in the region, but the stabilisation of the actor-network was temporary and has not yet reached an advanced stage of institutionalisation. Initiatives to promote KT maintain a high degree of amateurism and are highly dependent on the individual initiatives of staff rather than being consolidated in the collective dynamics. The dilution of an actor-network in these conditions can

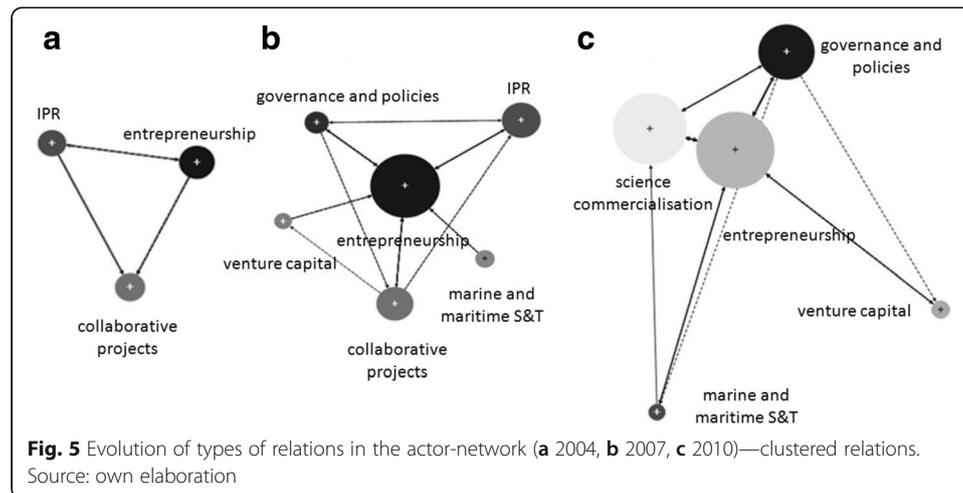
happen at any time and for any reason: lack of funding, key staff members quitting, misalignment with the strategic vision of the university management.

KT relations in the creation of the actor-network

A complementary way of looking at the relational data is using the notion of clusteriness in SNA. According to this concept, there are one or more groups of actors that share positive or neutral internal relations and negative or neutral relations to external nodes to the cluster (Lemieux and Ouimet 2004: 58). In practical terms, using this concept, the types of homogeneous relationships within the network can be illustrated by taking into consideration the specified attributes of the nodes. Figure 4 shows the clusters of relations in 2010. Note that in Fig. 4, the colours of the nodes do not represent the explicit attributes of particular nodes (for example, if they are firms or research groups, as seen in Fig. 3) but nodes with homogeneous types of linkages taking into consideration the original attributes of each node.

The clustering process allows uniting the nodes by the characteristic type of relation. Using the technique of ‘collapsing all groups’, it is possible to clearly plot the evolution of the importance of these relations and the linkages between them (Fig. 5). The analysis of clusters of relations is important to identify the evolution of activities within this actor-network. In 2004 (Fig. 5a) there were only three types of homogeneous relations which represented a relatively similar weight: the more





relevant entrepreneurship, the transfer of knowledge through collaborative projects and the PRs. In 2007 (Fig. 5b), a new set of typologies of linkages emerged, but entrepreneurship took an absolutely central role, almost monopolising the activities of KTO1.

Figure 5c represents exactly the same data as Fig. 4 for the year 2010, the difference being that the nodes are aggregated showing the total weight and centrality of each type of relation. Here, the central activity of KTO1 continues to be entrepreneurship support, though relatively less important. This type of activity is structured and has intense linkages with other dimensions. The cluster of relations associated with the stricter view of science commercialisation, i.e. patents and contracted R&D projects, interacts with entrepreneurship and governance policies. The scientific expertise of the university in marine and maritime sciences and technologies also corresponds with this strict view of science commercialisation unequivocally. This last dimension is a constant target for political governance (univocal dashed relation). The venture capital is related to the dimension of entrepreneurship and attracts the attention of regional governance.

Conclusions

Institutional change is based on endogenous and exogenous processes, for instance, the critical transitions in TH space, with the provision, withdrawal or reallocation of financial resources or programmatic efforts related to goals of KT. Different levels of action, policies, actors and behaviours are inter-related to institutionalise KT, which is a continuous, unfinished and precarious process, full of idiosyncrasies.

KT has been the subject of attention for decision-makers who foster development based on innovation. In Portugal, the recent transformation of KT is marked by the emergence of a broad range of innovation intermediation actors, especially those located in higher education institutions. This pathway is associated with the provision of public instruments which reinforced an intention that was already apparent in Portuguese universities since at least the beginning of the millennium.

The empirical component of this article paid attention to the creation of actor-networks in the KT process. It has two main contributions. First, ANT and SNA, two

approaches anchored in different traditions within the social sciences, may be used in a complementary way to analyse KT and TH transformations. The second contribution is that the deep comprehension of specific contexts for TH interactions benefits from a historical analysis of the institutionalisation process.

The results showed that institutional change can be analysed using the framework of ANT. The extended case study of a specific KTO (KTO1) illustrated the process of institutionalisation and collective engagement with a plurality of actors towards the creation of a consensus space in the TH interactions. The study focused on the emergence of KTO1 as an obligatory point of passage in KT within its territorial scope. The KTO was interpreted as a university bridge towards the TH space. The chronology of events presented the stabilisation of the actor-network, the different stages of translation and the institutionalisation of KT practices. The utilisation of ANT underlines how institutionalisation is always incomplete and full of tensions and contradictions.

The chronology of events facilitates understanding legitimisation and habituation within the TH relationships. It showed the self-reproducing processes and creation of new practices and vocabularies but also the conflicts and tensions that emerge during the institutionalisation of KT. The actor-network stabilisation was achieved during this period, and KTO1 created a consensus space around it. KTO1 was institutionalised as a formal university division and was seen as an obligatory point of passage in the TH. The movement towards the stabilisation of the actor-network involved many individual actors. This is evident both from the side of the university and from the side of the innovation actors. As the article demonstrated, the tensions remain and the actor-network is in constant change, with new interests emerging. No stabilisation is complete or definitive.

SNA, even if limited by the relational data obtained, also contributed to the discussion, mainly in two ways. The first finding suggests difficulties for the KTOs to connect with their internal stakeholders, such as the research groups within the universities. KTO1, despite being a division of the university, focused its support, on the one hand, to internal stakeholders who want to leave the campus and go to the market, for example, with a spin-off, and on the other hand, in the modernisation of existing firms that need to collaborate with the university. In this way a policy implication from the network analysis is that the attention to internal audiences should be improved and extended in the early stage of KTOs to gain legitimisation. University-industry relations can only be effective if KTOs actually know their own academic environment and research capabilities. KTOs should structure proactive strategies to meet internal capabilities with potentially interested demands from the economic fabric.

A second aspect refers to understanding the relative importance that KTOs give to particular modes of interaction, namely, to academic entrepreneurship. These are functions that universities are internalising in their intermediaries. This is a phenomenon that deserves attention because, as some authors underlined (Rieu 2014), the mimetic pressures of institutional architectures have stimulated a standardisation of innovation policies, namely, connecting science with 'society' but avoiding the clarification of what types of societal impacts are relevant and are strategic for an effective TH.

Appendix

Table 3 Network nodes betweenness (2010)

Node	Measure	Node	Measure	Node	Measure	Node	Measure	Node	Measure
KTO1	17669.319	S8	22.199	COMP20	0.333	S46	0	S89	0
MKT	4790.025	S9	22.199	COMP4	0.333	S47	0	S90	0
S28	646.106	S10	22.199	BA3	0	S51	0	S91	0
S15	335.614	S11	22.199	BS2	0	S52	0	S92	0
S44	327.245	S12	22.199	COMP1	0	S53	0	NGOV1	0
S58	320.714	S14	22.199	UnivDep4	0	S54	0	KTO4	0
S82	310.5	KTO2	19.369	COMP11	0	S55	0	KTO5	0
COMP10	310	BA2	15.513	COMP12	0	S56	0	KTO7	0
BP	253.174	S38	11.638	COMP13	0	S57	0	KTO8	0
RGOV3	190.457	S39	11.638	COMP18	0	S59	0	KTO9	0
IC	189.563	S30	11.548	COMP2	0	S60	0	KTO10	0
COMP15	186.465	S48	11.233	COMP3	0	S61	0	RG3	0
S36	147.779	S22	9.733	COMP6	0	S62	0	RG6	0
R&D	144.329	S45	7.951	COMP7	0	S63	0	RGOV6	0
S41	142.22	UniDep1	7.951	COMP8	0	S64	0	NGOV3	0
COMP16	127.071	UniDep2	7.951	S16	0	S65	0	RGOV7	0
S24	120.455	FPRIV2	4.879	S17	0	S66	0	NGOV5	0
FPUB1	114.708	KTO3	4.369	S18	0	S67	0		
S&T	105.64	KTO6	4.174	S19	0	S68	0		
COMP9	89.361	RGOV4	3.674	S20	0	S69	0		
COMP5	88.517	RGOV5	3.367	S21	0	S70	0		
S50	78.931	BS1	2.91	S23	0	S71	0		
RGOV1	63.17	RG2	2.717	S25	0	S72	0		
INNO	49.441	UniDep3	2.674	S26	0	S73	0		
RG1	39.924	COMP17	2.583	S27	0	S74	0		
KTN1	34.667	BA1	2.567	S29	0	S75	0		
IPR	33.715	NGOV2	2	S31	0	S76	0		
S1	27.706	RG4	1.971	S32	0	S77	0		
S13	26.415	FPRIV1	1.405	S33	0	S78	0		
S2	22.199	COMP14	1.369	S34	0	S79	0		
S3	22.199	S84	1.369	S35	0	S81	0		
S4	22.199	COMP19	1.167	S37	0	S83	0		
S5	22.199	S49	1	S40	0	S85	0		
S6	22.199	BS3	0.5	S42	0	S87	0		
S7	22.199	UniDep5	0.5	S43	0	S88	0		

Table 4 Network statistics (2010)

Vertices	157
Unique edges	278
Edges with duplicates	255
Total edges	533
Self-loops	1
Connected components	1
Single-vertex connected components	0
Maximum vertices in a connected component	157
Maximum edges in a connected component	533
Maximum geodesic distance (diameter)	4
Average geodesic distance	2.105
Graph density	0.0329
Minimum degree	1
Maximum degree	143
Average degree	5.146
Median degree	2.000

Additional file

Additional file 1: Translation of the abstract into Arabic. (PDF 236 kb)

Acknowledgements

Hugo Pinto acknowledges the support from FCT – Portuguese Foundation for Science and Technology (SFRH/BD/35887/2007 and SFRH/BPD/84038/2012). The present article was also supported by the FCT strategic project (UID/SOC/50012/2013). The author is thankful for the suggestions of Tiago Santos Pereira, Emanuela Todeva, and the two anonymous referees. The responsibility for the information and views set out in the article lies entirely with the author.

Received: 1 December 2014 Accepted: 27 February 2017

Published online: 20 April 2017

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