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# Exploring the relationship between service quality of technology transfer offices and researchers' patenting activity

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ABSTRACT

This article examines how the perceived quality of the service provided by technology transfer offices influences researchers' likelihood to patent their research results. A novel three-dimensional model is proposed aiming at analyzing the combined effect of service quality perceptions—service reliability, infrastructures and staff—alongside with factors that capture the university's regulatory framework and the profile and experience of the researcher. Results suggest that the profile of the researcher is much more critical for driving patenting activity than the quality of the services offered by the technology transfer office (TTO). However, the effect of the service quality delivered by the TTO is stronger when the researcher has less experience compared to researchers with a consolidated career.

## 1. Introduction

Universities are important sources of knowledge and scientific discoveries, thus both academics and policy makers are interested in how these institutions can develop their third mission function—understood as technology transfer—to become more adept at exploiting their knowledge-base and transfer it to the marketplace, going beyond the confines of the academic community (Gunasekara, 2006). Notwithstanding, executing this third mission is not that easy due to both individual and contextual factors that shape its success. While individual factors configure the researcher's willingness to participate in knowledge transfer and technology (KTT) activities (Olaya-Escobar et al., 2017), the latter—contextual factors—refer to the characteristics of the territory, as well as the specific structures, culture and support infrastructures within the university. This study considers both, yet, paying special attention on the role played by technology transfer offices (TTOs) in patenting, when combined with the university's regulatory framework and the profile of the researchers.

TTOs are commonly referred in the literature as support entities that assist in the consolidation of KTT activities within universities

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(Berbegal et al., 2012). They do so by acting as intermediaries or "knowledge brokers" between universities and companies (Villani et al., 2017; Beraza Garmendia and Rodríguez Castellanos, 2010). Their role is to boost the flow of knowledge and technological discoveries from universities (or research centers) to the industrial sector (Weckowska, 2015; Siegel et al., 2007) in the most efficient way (Brescia et al., 2016). Aiming at narrowing the gap between knowledge creation and knowledge exploitation many universities started creating TTOs (O'Gorman et al., 2008), standing as crucial nodes that connect suppliers and users of knowledge while supporting the endogenous potential of innovation in firms (Landry et al., 2013). The strategic nature of TTOs as key instruments for technological and economic development has led many authors to investigate them from different perspectives (see Olaya-Escobar et al. (2014) for an extensive review).

Research on TTOs is rich, yet, there are relevant aspects concerning their functioning that, up to date, remain under-examined. We refer to those aspects related to the quality of the service these offices provide, and their influence on researchers' likelihood to get involved in KTT activities. TTOs tend to specialize in the provision of services at different stages of the value chain of technology transfer activities and to benefit from the effects of complementarity between service offerings. How these services are delivered is of utmost importance as there is wide consensus that researchers do not necessary possess the skills for transferring their results into the marketplace. While academics are skilled at generating new knowledge, disclosing their ideas for industrial exploitation is a task that can be more easily performed with the assistance of specialized technical staff (Berbegal-Mirabent, 2018).

The relevance of the services provided by TTOs has recently started attracting attention among academics, questioning whether how the service is delivered does impact on technology transfer outcomes (Wu et al., 2015). In this respect, authors such as Markman et al. (2005), Owen-Smith and Powell (2001b) and Owen-Smith et al. (2002) found that—for the specific case of patents—the higher the service quality delivered by the TTO, the higher the predisposition of researchers to patent their research results. This finding is consistent with that of other works showing that TTOs' service quality together with TTO's personnel capacities (Lockett and Wright, 2005; Markman et al., 2005; Rasmussen and Borch, 2010), expertise (Swamidass and Vulasa, 2009), experience (Link and Siegel, 2005; Siegel et al., 2008; Thursby and Thursby, 2002), competence (Alexander and Martin, 2013; Siegel et al., 2007), and practice (Debackere and Veugelers, 2005; Resende et al., 2013) increases researchers' engagement in patenting activities. On the contrary, an unsatisfying experience with the TTO may be enough to abandon any patenting or other KTT endeavors (Owen-Smith and Powell, 2001b).

The profile of the researcher might also play a role in this decision process—to patent or not to patent—and thus, researcher's experience should be considered alongside service quality features of the TTO. The rationale behind this can be found in the current evaluation system of researchers. Promotions within academia are typically linked to publication records rather than engagement on KTT activities (Lafuente and Berbegal-Mirabent, 2019b). This implies that the strong incentives towards publishing—in order to create a reputation—will probably increase researchers' chances of being promoted which, in turn, might dilute researchers' willingness to be active in patenting. Likewise, in order to protect a discovery, researchers are typically asked to delay the publication until the patent has been filled (Campbell et al., 2000; Lee, 2000). These restrictions to keep confidential are an additional impediment for publishing, and consequently, for carving out an academic career. Finally, researchers may be interested in patenting their research results; yet, the uncertainty of generating non-patentable results is another factor that limits patenting (Baldini, 2011). The aforementioned reasons reinforce our argument that the profile of the researcher should not be underestimated.

The purpose of this study is thus to investigate the impact that service quality offered at technology transfer offices (TTOs) has over researchers' willingness to patent. The relevance of this topic stems from the identification of different strategies researchers might follow when deciding to patent. As previous studies suggest, researchers sometimes bypass the TTO (Goel and Göktepe-Hultén, 2018; Huyghe et al., 2016), making these infrastructures redundant. An alignment between researchers' incentives and the TTO is crucial in order to make the technology transfer process more efficient. Knowing more about researchers' perceptions of TTOs is of paramount importance in order to identify operations models for TTOs that make them better respond to their original purpose. Rooted in this context and based on the literature, a three-dimensional model is proposed considering the service quality delivered by the TTO (reliability of the service, staff and infrastructures), the regulation framework of the university and the profile and experience of the researcher. Due to diversity in professors' profile at universities, we posit that different profiles leading to high involvement in patenting might be observed.

Aiming to test this out, we conduct an empirical analysis where we examine which combination(s) of factors leads to patenting. The empirical application considers the case of Universitat Politècnica de Catalunya (Barcelona, Spain). A survey was designed and sent to all academic staff. However, only those researchers that used the services provided by the TTO were included in the study. The number of patents granted in the last 5 years was used as a measure of performance in patenting. Principal components analysis (PCA) was used to validate the scales that capture service quality and university regulation. Finally, the model was tested using qualitative comparative analysis (QCA), since the hypothesis guiding this research is that researchers' motivations to patent are diverse, consequently, it is necessary to investigate if different combinations of factors lead to a similar result (patents).

This study contributes to the literature in two main ways. First, this study is one of the first that examines the quality of the service provided by TTOs. An exhaustive review of the literature reveals a lack of studies that empirically test this effect. As pointed out by Franco and Haase (2015), TTOs' service quality can be helpful in strengthening university-industry partnerships; therefore, identifying under which circumstances TTOs are appealing to scientists is worthy to be studied further. Second, by means of a qualitative comparative approach, we are able to confront different strategies that researchers use when patenting. Understanding the rationale behind these strategies is important for technology policy, as universities are looking for new ways to make their TTOs more effective and not falling short in their mandates.

The remainder of the article is structured as follows. The next section provides an overview of the existing literature on service provision of TTOs. Then, the methodology section follows, describing the research design, the sample and the data collection process. Results are later presented and discussed. The paper ends with the concluding remarks followed by the limitations and suggestions for future research.

## 2. Theoretical background

### 2.1. Support university services for KTT activities

Knowledge and technology transfer activities seek to transform the results of research into applications with economic and social impact (Berbegal-Mirabent et al., 2015). Institutional support for KTT activities is a critical factor to facilitate university-business exchange (Franco and Haase, 2015; Petruzzelli and Rotolo, 2015), which is known to be a complex process (González-Pernía et al., 2013).

To facilitate KTT processes, three requirements are in order, namely, an appropriate knowledge stock (Arthur, 2009), a favorable regulatory framework (Bercovitz et al., 2001; Geuna and Rossi, 2011; Kenney and Patton, 2011; Di Gregorio and Shane, 2003) and adequate support infrastructures (González-Pernía et al., 2013; Villani et al., 2017). Concerning the first one, there is a widespread agreement that universities are relevant sources of knowledge for innovation (Etzkowitz and

Leydesdorff, 2000). As for the second one, after the promulgation of the Bayh-Dole Act in the United States, many countries have introduced policies to encourage the transfer of research results to the market (Siegel et al., 2007; Wright, 2007). These policies have been accompanied by the establishment of administrative procedures and internal processes at university level that have reduced knowledge transfer restrictions and encouraged researchers to participate in KTT activities (Czarnitzki et al., 2007). Universities have managed to create protocols to regulate the way researchers, universities and businesses interact and to encourage applied research. Notwithstanding, each university approaches its objective function in a distinctive way (Berbegal-Mirabent et al., 2013), consequently, different approaches to regulation policies—aligned with universities' own values and strategic vision—might be observed. Lastly, the technological infrastructure provided by the university as well as the quality of its networks with the industry, seem to be critical for channeling new technologies into the market (Di Gregorio and Shane, 2003; Wright, 2007). Soft structures—e.g., alignment of interests, organization culture—also play a critical role (Engel and Del-Palacio, 2009), hastening or hindering the development of KTT activities.

A way to institutionalize KTT activities has been the creation of specific units or organizational structures that provide assistance and promote the collaboration between researchers and industry partners (Olaya-Escobar et al., 2014). Landry et al. (2013) identify four types of organizations created with the objective of supporting KTT. The first group includes University TTOs. A second group consists of public research organizations. A third typology are Community College Technology Transfer Offices (CTTOs), similar to University TTOs but located in community colleges and therefore less research-oriented. Finally, regional organizations stand out. For the purpose of this article, the first group of the above described will be the main objective of study.

TTOs have been addressed in the literature as the formal gateway between the university and the industry (Petruzzelli, 2011), yet, not just their existence but how they are managed—and consequently, their productivity—is what makes them successful at converting scientific knowledge into practical applications. TTOs are responsible, among other tasks, of licensing, intellectual property valuation, and support and incubation of newly created companies (Beraza Garmendia and Rodríguez Castellanos, 2010). According to Brescia et al. (2016) TTOs are organic entities, created with the purpose of managing university KTT processes more efficiently. Many universities have established TTOs to encourage scientists to consider marketing their research results and support them in this process (O'Gorman et al., 2008). TTOs thus act as intermediaries between researchers and companies (Villani et al., 2017) with a series of activities that encourage the commercial exploitation of research results (Weckowska, 2015). They are crucial nodes that connect knowledge supply with knowledge demand, improving the endogenous potential of innovation in companies (Landry et al., 2013).

The World Intellectual Property Organization, WIPO (2011) states that TTOs should ideally have a combination of competencies that allow them to successfully perform their basic functions. Some of the most critical competences include legal, technical and commercial guidance with a multidisciplinary approach. The experience, infrastructure, size, networks and personnel, are characteristics of TTOs that can enhance the commercialization of research results. If properly managed, TTOs are entities of great usefulness, not only for the professional support and services they provide, but also because its organization and infrastructure can mitigate the costs associated with KTT activities.

### 2.2. Quality of the service provided by the TTO

TTOs' productivity depends on a variety of factors including, among others, its structure and staff (Petruzzini, 2011), which are undoubtedly mirrored in how the service is delivered, and consequently, these two characteristics are perceived by academics when interacting with them.

TTOs tend to specialize in the provision of services at different stages of the valorization and commercialization value chain, and to benefit from the effects of complementarity between services offered. In Landry et al. (2013) 21 different services are identified. Owen-Smith and Powell (2001b) state that, although it is recommended to have a wide range of services, the most critical aspect is the quality of these services. That is, depth appears to be more critical than breath, which suggests that specialization is desirable. For the specific case of patents, Markman et al. (2005) note that the better the quality of the service provided by the TTO the greater the predisposition of researchers to get involved in patenting. These results are consistent with the studies of Owen-Smith and Powell (2001b) and Owen-Smith et al. (2002), who found that the willingness of researchers to patent may be affected by their perception of the ease of working with the TTO. Contrarily, a frustrating interaction with the TTO may be a sufficient reason to convince the researcher that benefits from IP protection do not outweigh their cost (Owen-Smith and Powell, 2001b). The abovementioned reasons lead us to argue that the quality of the service provided by the TTO is a relevant factor that researchers take into account when considering spreading their inventions to the marketplace (Wu et al., 2015).

Service quality provision has been widely studied and documented in the academic literature. In this respect it is worth highlighting the contributions of Parasuraman et al. (1985, 1988). These authors developed a quality measurement instrument that contains five dimensions—and a total of 22 items—which under the name of SERVQUAL evaluates the reliability, the characteristics, the response capacity, the security and the empathy of a service. The aforementioned works have been the starting point of many others that have analyzed the perception of customers/users in various industries such as healthcare (Mecev and Goles, 2015; Jandavath and Byram, 2016; Parmata et al., 2016; Vryoni et al., 2017), banking sector (Kumar et al., 2018), insurance (Ghosh, 2016), online shopping (Joo et al., 2012), logistics and transportation (Gajewska and Grigoroudis, 2017; Jahmani, 2017). However, little research has been conducted in the specific domain of TTOs. From these studies, we can highlight the work of Pakes (2013), who presents a tool to measure the quality of the services provided by technology and innovation offices. An exhaustive review of the existing literature reveals an absence of studies that empirically prove the effect of TTO service quality on KTT activities, notwithstanding, there are several works examining service quality in the higher education, but mainly focused in the teaching dimension (Ahmed et al. 2010; Felcio Soares and Sousa, 2015; Dalati and Al Hamwi, 2016; Lee et al., 2017).

### 2.3. Success factors for the development of KTT activities

Previous literature has tried to link the resources and capabilities of TTOs and the success of marketing activities as well as innovation drive (González-Pernía et al., 2013). Among the determinants of success, the reliability of the service, TTOs infrastructure and the quality of the staff (experience and empathy of the staff) stand as key assets. These determinants are aligned with the dimensions proposed by Parasuraman et al. (1985, 1988) to measure the quality of a service.

The reliability of the service should be understood as the quality and quantity of the services provided by the TTO such as legal advice, information and guidance on commercial viability, specific advice on the business area, flexible and adequate policies and knowledge, experience and resources for supporting technology transfer processes. As per the TTO infrastructure, beyond the service portfolio, relevant factors include the coordination capacity and processing of information of the TTO, its degree of autonomy, the existence of an enabling incentive system, collaboration with industry, the facilities and the experience that the office has acquired over the years (Feldman et al., 2002; Di Gregorio and Shane, 2003; Smilor and Matthews, 2004; Lockett and

Wright, 2005; Markman et al., 2005; Arthur, 2009; Caldera and Debande, 2010; Lafuente and Berbegal-Mirabent, 2019a). Concerning the composition of TTO staff, previous works suggest that size and capacity (Owen-Smith and Powell, 2001a; Markman et al., 2005) matter, while Smilor and Matthews (2004) go a step further in this direction and underline the importance of the "quality" and not just the "quantity", where quality refers to staff's skills and knowledge regarding KTT processes (e.g., patents, know-how of legal or technological domain, the capacity to evaluate the potential of inventions, etc.). In a similar vein, Lockett and Wright (2005)—in their research focused on the study of why some universities are more likely to create spin-offs than others—suggest that training of staff working in the TTOs is a fundamental factor, which can influence the service provision and enhance employees' empathy and willingness to support researchers. In the light of the above arguments, the following propositions are articulated:

Proposition 1: Positive perceptions about TTO's service reliability are associated with a higher involvement of researchers in patenting activities.
Proposition 2: Positive perceptions about TTO's physical facilities (quality of the infrastructures) are associated with a higher involvement of researchers in patenting activities.
Proposition 3: Positive perceptions about TTO's staff (experience, sensitivity, empathy) are associated with a higher involvement of researchers in patenting activities.

Besides the above factors within the TTO, there are other external factors shaping KTT activities, being regulation the most relevant one (Olaya-Escobar et al., 2017). Since the enactment of the Bayh-Dole Act in the United States, many countries have introduced similar frameworks aimed at ensuring intellectual property rights and at increasing the effectiveness through which university research results were picked up by industry and brought to practice. Such policies have spurred the establishment of internal university procedures that vary from university to university. Nevertheless, a highly elaborate administrative apparatus might produce the opposite effect, and restrict the diffusion of these research results (Mowery et al., 2001). In this line, both Franco and Haase (2015) and Olaya-Escobar et al. (2017) indicate that bureaucracy, an adverse legal framework, and the lack of organizational support are the main barriers hindering university-industry cooperation to develop in its full potential. Accordingly, we postulate that:

Proposition 4: A flexible and favorable regulation framework for the researcher is associated with a higher involvement in patenting activities.

Individual factors might also play a role. Link and Siegel (2005) emphasized the importance of the researcher having previous knowledge and experience in KTT activities. Said differently, researchers who have previously worked in collaboration with the industry will be more open to engage in new university-industry activities. In this sense, previous literature supports the argument that scientists that are actively involved in university-industry partnerships (e.g. through R&D contracts) are more likely to engage in patenting initiatives, as it represents a secure way to obtain protection of the research results (Kim and Song, 2007; Petruzzelli, 2011). Similarly, Link et al. (2007) observed that experience—measured in years—exerts a positive impact. Stephan et al. (2002) also studied this relationship and found that the likelihood of applying for a patent is related to previous publication experience. Carayol and Matt (2004) further validate this result and observed that—at least in some disciplines—patents are by-products of scientific work instead of substitutes (Breschi et al., 2007). Thereby, three propositions emerge:

Proposition 5: Researcher's previous experience in the industry is associated with a higher involvement in patenting activities.
Proposition 6: Researcher's previous experience in research is associated with a higher involvement in patenting activities.
Proposition 7: Researcher's previous involvement in university-industry partnerships, such as R&D contracts, is associated with a higher involvement in patenting activities.

The studies of Ryan (2014) and Ryan and Berbegal-Mirabent (2016) suggest that motivations—both intrinsic and extrinsic—are the fundamental basis to understand how researchers perform. Adopting this line of thought, we posit that researchers' motivations to participate in KTT activities differ depending on their contractual situation. For young academics in a weaker contractual position—temporary contract—their academic career will be very determined by their ability to publish, with strong incentives to do that. As observed in Berbegal-Mirabent and Sabaté (2015) academic scientists base their careers mainly on reputation, which, in turn, is mainly based on publications in indexed scientific journals. However, this orientation towards publishing—which increases their probabilities of being promoted—inhibits the possibilities of patenting (Lafuente and Berbegal-Mirabent, 2019b). On the contrary, academics with a long-term employment contract and with a consolidated career do not have this pressure for publishing, and therefore, other incentives determine their choices (Fullwood et al., 2013; Baldini, 2011; Wu et al., 2015). This argument is related to the idea that individual incentives change gradually over time (Calderini et al., 2007).

Proposition 8: A permanent position in academia is linked to a higher involvement in patenting activities.

## 3. Data and method

### 3.1. Sample and data collection

A survey was designed and sent by email to all faculty members—in charge of conducting teaching, research and KTT activities—working at the Universitat Politècnica de Catalunya – BarcelonaTech (UPC) (Catalonia, Spain). This university is a public institution which is highly committed with research and higher education in the fields of engineering, architecture, sciences and technology. Over the years, UPC has become one of the leading technical universities in Europe with more than 57.7M€ coming from R&D projects in 2018.

Data were collected from August to December 2015. Of the 509 returned surveys, 249 were fully completed. Yet, only 130 surveys were valid as, for the purpose of this study, we are only interested in those faculty members that used the services of the TTO. Accordingly, our sample size is of 130. Table 1 shows the characteristics of the respondents included in the final sample.

### 3.2. First stage: scale validation

In a first stage, we designed and validated the questionnaire to be sent out to. A three-dimensional scale was used, adapting the SERVQUAL scale (Parasuraman et al., 1985, 1988). Through this instrument we aim at capturing researchers' perceived quality of the service provided by the TTO. The three dimensions are reliability (items CS1 to CS5), infrastructure (I1 to I3) and staff, which explicitly refer to the perceived characteristics of the TTO. As for the later dimension, we distinguished between experience (PX1), sensitivity (PS1 and PS2) and empathy (PE1 and PE2). A fourth dimension was included containing items regarding the regulation of the university (items N1–N4). Table 2 shows the full list of items. For each of these items, respondents were asked to indicate their level of agreement/disagreement on a 5-point Likert scale, ranging from completely disagree (1) to completely agree (5). The questionnaire also contained a section to gather information about the profile and KTT performance of the respondents.

**Table 1**
Profile of the respondents.

| Gender | Number | % |
|---|---|---|
| Female | 17 | 13.08 |
| Male | 113 | 86.92 |
| Age | Number | % |
| Less than 30 years | 2 | 1.54 |
| Between 30 and 34 years | 9 | 6.92 |
| Between 35 and 39 years | 11 | 8.46 |
| Between 40 and 49 years | 36 | 27.69 |
| Between 50 and 59 years | 50 | 38.46 |
| Greater than 60 years | 22 | 16.92 |
| Academic level | Number | % |
| PhD | 112 | 86.15 |
| Non PhD | 18 | 13.85 |
| Contract type | Number | % |
| Permanent contract | 105 | 80.77 |
| Temporal contract | 25 | 19.23 |
| Previous industry experience | Number | % |
| Staff with experience outside academia | 68 | 52.31 |
| Staff without experience outside academia | 62 | 47.69 |
| Output | Number | % |
| Patents (last 5 years) | 89 | – |

Because the purpose of this study is to investigate how the combination of these dimensions—together with the profile of the researcher and the institutional framework—shape researchers' performance in patenting, a principal component analysis was run in order to group the items and extract the factors to be used in the second stage analysis. The suitability of using factor analysis as a sampling methodology was verified. The calculation of the sphericity test of Barlett yielded a $\chi^2 = 1546.070$ with 136 degrees of freedom and a $p$-value $= 0.000$, rejecting the null hypothesis and verifying that the dataset was appropriate for factor analysis. The Kaiser–Meyer–Olkin value test further corroborated the suitability of grouping the items into factors (KMO $= 0.898$, $p$-value $= 0.000$).

Next, an exploratory factor analysis was executed retaining those factors with eigenvalues greater than 1. As shown in Table 3, the items were grouped according to the expected dimensions, corroborating the validity of the measurement of the different constructs, and explaining 73.13% of the total variance. The next step consisted of analyzing items included in each factor. We used an orthogonal rotation method (varimax) which guarantees that factors are not correlated, and thus, problems of multicollinearity are avoided (Field, 2009). The results are shown in Table 3, including the percentage of variance extracted and the loadings of the items ($\geq 0.3$) that best explain each factor.

The next step consisted in analyzing the unidimensionality of each factor. The software used was SPSS. In all instances the analysis extracted only one factor, corroborating the adequacy of the approach.

**Table 3**
Matrix of the components extracted using PCA and the varimax rotation.

| Item | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| CS1 | | 0.4779 | | |
| CS2 | | 0.3806 | | |
| CS3 | | 0.5182 | | |
| CS4 | | 0.4154 | | |
| CS5 | | 0.4036 | | |
| I1 | | | | 0.6401 |
| I2 | | | | 0.6492 |
| I3 | | | | 0.3513 |
| PX1 | 0.2929 | | | |
| PS1 | 0.4594 | | | |
| PS2 | 0.4667 | | | |
| PE1 | 0.5064 | | | |
| PE2 | 0.4300 | | | |
| N1 | | | 0.5256 | |
| N2 | | | 0.4653 | |
| N3 | | | 0.4540 | |
| N4 | | | 0.4796 | |
| % of variance extracted | 44.73% | 12.35% | 9.30% | 6.75% |

**Table 4**
Reliability analysis.

| Factor | Item | Loading | Reliability analysis |
|---|---|---|---|
| Reliability of the service | CS1 | 0.777 | Cronbach's alpha: 0.9197 |
| | CS2 | 0.802 | CR: 0.9177 |
| | CS3 | 0.803 | AVE: 0.6910 |
| | CS4 | 0.871 | |
| | CS5 | 0.897 | |
| Infrastructure | I1 | 0.926 | Cronbach's alpha: 0.7837 |
| | I2 | 0.945 | CR: 0.8226 |
| | I3 | 0.387 | AVE: 0.6334 |
| Staff | PX1 | 0.732 | Cronbach's alpha: 0.8926 |
| | PS1 | 0.786 | CR: 0.8939 |
| | PS2 | 0.829 | AVE: 0.6282 |
| | PE1 | 0.761 | |
| | PE2 | 0.849 | |
| Regulation | N1 | 0.756 | Cronbach's alpha: 0.8510 |
| | N2 | 0.760 | CR: 0.8394 |
| | N3 | 0.805 | AVE: 0.5673 |
| | N4 | 0.687 | |

CR: Composite Reliability. AVE: Average of the variance extracted. All loadings are significant at 1%.

Table 4 presents the results of the reliability analysis. Both the Cronbach's alpha and the composite reliability (CR) exceed the cut-off point of 0.7, indicating good internal consistency between the elements within each factor. The average variance extracted (AVE) also exceeds the cutoff point of 0.5 (Nunnally and Bernstein, 1994) for all factors.

**Table 2**
Items included capturing the perceived service quality of the TTO.

| | | | |
|---|---|---|---|
| Reliability of the service | | CS1 | The TTO provides information on the commercial viability of the technology / invention |
| | | CS2 | The TTO offers sufficient legal advice |
| | | CS3 | The TTO advises in the business area |
| | | CS4 | The TTO has flexible policies for technology transfer |
| | | CS5 | The TTO dedicates the necessary resources in the processes of technology transfer |
| Infrastructure | | I1 | The TTO physical facilities of your university are visually attractive |
| | | I2 | The TTO physical facilities of your university are modern |
| | | I3 | The size of the TTO (number of workers) is sufficient to cover the KTT support activities of the university |
| Staff | Experience | PX1 | TTO employees have sufficient knowledge about technology transfer processes |
| | Sensitivity | PS1 | TTO employees are ready to help researchers at any time |
| | | PS2 | The TTO offers the services on the previously agreed dates |
| | Empathy | PE1 | The employees of the TTO are receptive and attentive |
| | | PE2 | The employees of the TTO are of great help giving support to the activities of KTT |
| Regulation | | N1 | The internal regulations of the university encourage and stimulate professors to get involved in KTT activities |
| | | N2 | University administrative processes promote the development of new KTT activities |
| | | N3 | The university actively promotes entrepreneurship |
| | | N4 | The importance of knowledge and technology transfer is clearly communicated |

**Table 5**
Matrix of correlation of latent factors.

| Factors | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Reliability of the service | *0.8313* | | | |
| Staff | 0.6128 | *0.7926* | | |
| Regulation | 0.5867 | 0.4427 | *0.7532* | |
| Infrastructure | 0.2585 | 0.3954 | 0.2315 | *0.7959* |

The analysis of the discriminant validity revealed the suitability of the data for the proposed model. As shown in Table 5, the square root of each of the AVE is greater than the elements outside the diagonal—they appear in italics on the diagonal—(Fornell and Larcker, 1981).

### 3.3. Second stage: Comparative qualitative analysis

In this study we argue that different patterns might be observed with regards researchers' involvement in patenting. One method that allows conducting this type of analysis is qualitative comparative analysis (QCA). This approach facilitates the determination of which combinations of antecedent conditions—perceived service quality of the TTO, legal framework within the university and researchers' profile—are more likely to lead to a specific result—patents—(Longest and Vaisey, 2008). QCA involves the analysis of the necessary and sufficient conditions to produce an outcome (Meyer et al., 1993; Wu et al., 2014). This analysis is suitable for cases with small data samples, but allows the generalization of conclusions and implications for larger populations (Huarng, 2015). QCA assumes complex causality and focuses on asymmetric relationships between independent variables (antecedent conditions, using QCA terminology) and the dependent one (namely, outcome or result). A configuration is a combination of factors that is minimally necessary and/or sufficient to obtain a specific result (Meyer et al., 1993). Antecedent conditions can be positive, negative or absent.

QCA uses Boolean logic, meaning that both the antecedent conditions and the outcome must be transformed to values ranging from 0 to 1, indicating their level of belongingness to the set (1 = full membership, 0 = full non-membership). The transformation process is called calibration. For dummy variables, a transformation in crisp-set terms (csQCA) is recommended, whereas for variables with continuous values, a transformation into fuzzy-sets terms (fsQCA) is required (Ragin, 2008a). In the latter case transformed values range from full membership (1) to full non-membership (0). The crossover point (0.5) indicates maximum uncertainty (neither inside nor outside the set).

In the next step, the truth table is built, that is, a matrix with $2^k$ rows where $k$ stands for the number of antecedent conditions. Each empirical case corresponds to a configuration that depends on the antecedent conditions that the case meets. Each column represents a condition (Fiss, 2011). The last step consists in reducing the number of rows in the truth table. The Quine-McCluskey algorithm (Quine, 1952) allows obtaining the minimum feasible number of configurations. Each configuration is minimally sufficient to produce the result. The row reduction process is based on two criteria: coverage, which indicates the empirical relevance of a solution, and consistency, which quantifies the degree to which cases that share similar conditions show the same result (Ragin and Fiss, 2008b).

For the purpose of the analysis, the result to be explained is the number of patents granted in the last 5 years. The antecedent conditions refer to the four dimensions extracted in the first stage (reliability of the service offered at the TTO, TTO infrastructure, TTO staff, and university regulation). In addition, we included five antecedent conditions to control for the profile of the researcher. These are: experience (both in academic and working in the industry), prior experience in university-industry agreements (proxied by the number of R&D contracts between the university and the company in which the researcher has participated in the last 5 years), the type of contract (distinguishing between permanent and temporal), and gender. Lastly, following previous works that indicate that geographical location might also exert an influence (Wright et al., 2008) we also included an antecedent condition accounting for this effect. Universitat Politecnica de Catalunya is a multisite university with campuses in Barcelona but also in other second-ranked cities (Castelldefels, Manresa, Sant Cugat del Vallès, Terrassa and Vilanova i la Geltrú). By including this variable in the analysis we want to test if being located in Barcelona makes a difference.

Table 6 provides a full description of the variables of interest, including the details of the calibration process.

## 4. Results

Before proceeding with the analysis, we examine if any of the antecedent conditions is necessary to explain the outcome. According to Schneider et al. (2010) a condition is deemed as necessary when its consistency value exceeds the threshold value of 0.9. Table 7 shows the consistency and coverage values. Given that any of them display a value higher than 0.9 we can conclude that there is no necessary condition. The only exception is found in the variable gender (in its negated version). However, since the value is just at the threshold value (0.9053) and the coverage value is relatively low (0.3140), we can also introduce this variable (gender) in the model.

**Table 6**
Definition of variables and calibration values.

| Factors | Description | | Membership threshold values | | |
|---|---|---|---|---|---|
| | | | Full non-membership | Crossover point | Full membership |
| Outcome | Patents awarded[a] (last 5 years) | | 0 | 0 | 2 |
| Antecedent conditions | Reliability of the service[a] | | −2.3870 | −0.2856 | 2.4544 |
| | Infrastructure[a] | | −1.6129 | 0.1000 | 1.9676 |
| | Staff[a] | | −2.2030 | 0.0767 | 2.3521 |
| | Regulation[a] | | −2.3745 | 0.1913 | 2.0152 |
| | IndExp[a]: Industry experience (years) | | 0 | 1 | 10 |
| | ResExp[a]: Research experience (years) | | 6.5 | 20 | 30.5 |
| | R&D contracts[a] (last 5 years) | | 0 | 1 | 6 |
| | Contract type[b] | 0: Temporal<br>1: Permanent | 0 | | 1 |
| | Center[b] | 0: Territorial<br>1: Barcelona | 0 | | 1 |
| | Gender[b] | 0: Male<br>1: Female | 0 | | 1 |

[a] Observations falling in the percentile-90 are considered to represent full set membership. Percentile-10 is the threshold value for indicating full non-membership. The crossover point is defined by the median.
[b] Variables expressed in crisp-set terms.

**Table 7**
Analysis of necessary conditions.

| Conditions* | Consistency | Coverage |
|---|---|---|
| Reliability | 0.5856 | 0.3383 |
| ~Reliability | 0.6619 | 0.4173 |
| Infrastructure | 0.5425 | 0.3564 |
| ~Infrastructure | 0.6912 | 0.3851 |
| Staff | 0.5198 | 0.3271 |
| ~Staff | 0.6861 | 0.3971 |
| Regulation | 0.5639 | 0.3427 |
| ~Regulation | 0.6471 | 0.3871 |
| IndExp | 0.4124 | 0.4277 |
| ~IndExp | 0.8364 | 0.3555 |
| ResExp | 0.6744 | 0.4024 |
| ~ResExp | 0.5157 | 0.3142 |
| R&D contracts | 0.6749 | 0.4963 |
| ~ R&D contracts | 0.5241 | 0.2678 |
| Contract type | 0.8234 | 0.3073 |
| ~ Contract type | 0.1766 | 0.2768 |
| Center | 0.5797 | 0.2582 |
| ~Center | 0.4203 | 0.3921 |
| Gender | 0.0947 | 0.2182 |
| ~Gender | 0.9053 | 0.3140 |

*The symbol ~ represents the absence of the condition.

Table 8 shows the 11 recipes—configurations—that yield to patenting. Because there is no one solution that predicts the outcome, but several valid ones, it can be concluded that our initial intuition that there is no unique causal path to explain researchers' engagement in patenting, seems to be correct.

Following the recommendation of Ragin (2009), this study reports the intermediate solution. The notation follows the convention proposed by Ragin and Fiss (2008b), where the black circles (●) indicate the presence of the condition and the whites ones (○) indicate their absence. Blank cells represent ambiguous conditions.

The consistency of the global solution is 0.8073 and the coverage 0.4075, showing a good fit of the model. At the individual level of each configuration (or recipe), row coverage values range between 0.0166 and 0.175, and consistency values between 0.8136 and 1.000, revealing acceptable fit indices.

## 5. Discussion

The results in Table 8 show that service quality of the TTO—measured as service reliability, infrastructures, and staff (experiences, sensitivity and empathy)—does not seem to play a paramount role on patenting activities if the researcher is experienced and has a consolidated academic career. These results are consistent with those obtained by Wu et al. (2015) who found that for patent licensing, the individual characteristics of the researcher are more important than the assistance provided by the TTO. On the contrary, the service quality of the TTO—in terms of staff and infrastructures—is relevant when researchers do not have neither industry nor research experience, as evidenced from a vertical reading of Table 8.

Diving deeper into the results, it can be observed that infrastructures play a little role. In fact, they only appear to be relevant in two configurations (#2 and #8), when this condition is combined with positive perceived quality delivered by TTO staff and an enabling regulation environment. Yet, service reliability seems to be less dependent to other quality dimensions of the TTO.

Regarding the factor related to university regulation, although it only appears in 4 configurations (#2, #3, #7 and #8) it is found to be relevant when the researcher is not experienced—young researchers who are in the process of consolidating their academic careers. Consequently, we can conclude that regulations, if appropriate designed can help researchers getting involved in patenting.

Another remarkable finding is that previous involvement in R&D contracts seems a desirable condition to explain the outcome—this trend is found in 9 out of the 11 configurations. The rationale behind this effect is that R&D contracts might entail the starting point of a new technological development, and thus, the possibility of protecting it through a patent. On the one hand, the industry has an interest in solving a specific problem. On the other hand, researchers can contribute with their know-how. The result is the protection of the invention and its exploitation and valorization in the market in the form of a patent. This explanation is aligned with previous literature which signals that patenting is highly linked to university-industry agreements (Thursby and Thursby, 2002; Markman et al., 2005).

Another antecedent condition that deserves special attention is the type of contract. From the table, it can be inferred that in most of the configurations researchers enjoy of a permanent contract with the university (in 8 occasions, compared to 3 in which the researcher has a temporary one). This result yields to two readings. First, that stability allows researchers to have greater autonomy and security, thus, they get involved in patenting once they have consolidated their careers. As highlighted by Wu et al. (2015), Fullwood et al. (2013) and Baldini (2011), researchers with a fixed-term contract and with a consolidated career are more likely to engage in KTT activities, as they have achieved a certain degree of professional security. Second, motivations—and particularly extrinsic ones—drive researchers' activities. A researcher with a temporary contract is still in the process of accreditation for a stable position. Calderini et al. (2007) argues that researchers' individual incentives change gradually over time as their career consolidates. Accreditation and promotion systems reward publications (Berbegal-Mirabent and Sabaté, 2015) and participation in competitive R&D projects instead of other forms of KTT, therefore

**Table 8**
Configurations of antecedent conditions sufficient to enter.

| Conf. id | Antecedent Conditions | | | | | | | | | | Coverage | | Consistency |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Reliability | Staff | Infrastructure | Regulation | Industry experience | Research experience | R&D contracts | Contract type | Center | Gender | Row | Unique | |
| 1 | ○ | ○ | ○ | ○ | | ○ | ● | ○ | ○ | ○ | 0.0457 | 0.0373 | 0.9676 |
| 2 | ○ | ● | ● | ● | ○ | ○ | ○ | ○ | ○ | | 0.0398 | 0.0278 | 0.9231 |
| 3 | ○ | ○ | ○ | ● | | ○ | ● | ● | ● | ○ | 0.1041 | 0.0219 | 0.8889 |
| 4 | ○ | ○ | ○ | ○ | ● | ● | ● | ● | | ○ | 0.1396 | 0.0163 | 0.8574 |
| 5 | ● | ○ | ○ | ○ | | ● | ● | ● | ● | ○ | 0.1705 | 0.0612 | 0.8136 |
| 6 | ● | ○ | ○ | | ● | ● | ● | ● | ● | ○ | 0.1156 | 0.0105 | 0.8312 |
| 7 | ○ | ● | ○ | ● | ● | ○ | ○ | ○ | ○ | ○ | 0.0194 | 0.0074 | 0.8837 |
| 8 | ○ | ● | ● | ● | ○ | ○ | ● | ● | ○ | ○ | 0.0439 | 0.0163 | 0.8687 |
| 9 | ○ | ○ | ○ | ○ | ○ | ● | ● | ● | ● | ● | 0.0270 | 0.0271 | 0.8154 |
| 10 | ● | ● | ○ | ○ | ● | ○ | ● | ● | ● | ○ | 0.0763 | 0.0066 | 0.9803 |
| 11 | ○ | ● | ○ | ○ | ● | ● | ● | ● | ○ | ● | 0.0166 | 0.0166 | 1.0000 |

Coverage of the solution:0.4075
Consistency of the solution: 0.8073

incentives to engage in other KTT activities such as patent licensing are low, and are typically subject to intrinsic motivations (Olaya-Escobar et al., 2017).

As for the two remaining antecedent conditions, location seems not to be determinant, as half of the configurations benefit researchers located in Barcelona, while the other half to those researchers located in the other campuses. Lastly, gender shows a pattern that reflects the current distribution of staff working at the university under study. Almost 87% of the respondents were men—a proportion that approximates the real composition of the workforce of the university (24% women and 76% men)—therefore, it is not surprising that there are only two configurations (#9 and #11) referring to women. Yet recipe #9 is very close to #5 (referring to men), with the only exception of service reliability, which seems to be a relevant condition for men, whilst not being necessary for women. Similarly, configurations #4 and #9 are really close to each other, except for the perceptions of staff (which is found to be relevant for women).

Following the recommendation of Ragin (2008a), the configurations with the highest row coverage (#4 and #5) should be more carefully examined, as they cover a higher proportion of cases. In the case of recipe #4, it is observed that, although the service provided by the TTO does not stimulate engagement in patenting, if the researcher has a sound experience in both academia and industry, is active in R&D contracts and has a fixed-term contract, the likelihood of patenting increases. This configuration mainly applies to male researchers. Configuration #5 presents some similarities. In this case, the non-effect regarding previous research experience is compensated by a TTO that provides information and reliable advice, especially if located in Barcelona.

## 6. Conclusions

The relationship between universities and the industry is not straightforward. The knowledge generated in both domains frequently finds it difficult to transcend a domain and enter in the other one. However, this knowledge exchange can offer rich and high potential opportunities. To overcome this challenge, hybrid infrastructures have been created that—acting as interfaces in the science-technology system—assume a key role for the effective establishment of information flow and knowledge transfer between universities and companies. These entities or organizations, known as TTO have been studied in the scientific literature. Although several studies consider the service quality provided by TTO as a critical factor to increase KTT activities and strengthen the university-company relationship, an exhaustive review of the literature has revealed an absence of studies that empirically test the effect of the TTO service quality. In this sense, one of the main contributions of this paper is the analysis of the service quality of TTOs and their influence on the interest of researchers in patenting. Additionally, through empirical using the QCA methodology, different patterns that can potentially increase KTT activities are identified, from those, each university should choose its most appropriate strategy based on its own characteristics.

Our results reveal the service quality delivered at TTOs does influence researchers' patenting activities, although this effect being different depending on the career stage of the researcher. TTO's service quality is more critical when the researcher does not have a consolidated career and experience and does not have job stability or is in a promotion process. These results are probably a consequence of the incentive system currently in place at universities, certainly at Spanish universities, which constitute the empirical setting of the current research, but also elsewhere. Nowadays, the incentive system encourages researchers to heavily focus on publications which are tightly linked to promotion and salary decisions. Patent applications and patenting activities do not significantly add value in a young researcher curriculum. For that reason, the patenting willingness of young researchers is rather low. If universities or society at large would like to change this situation and increase the number of KTT activities performed by young researchers, there are only two potential paths: either the researchers' incentive system changes and patent filing is appreciated and considered salary and promotion wise—something that is difficult to foresee in the short/medium term—; or, alternatively, TTO services facilitate so much the process of patent application that even researchers without any strong particular incentive to do it would do it because it does not require much effort. This second option is easier to implement as it only requires a refinement and improvement of TTOs' services.

On the other hand, researchers with a consolidated career and work experience are not affected by the TTO service quality but probably their actions might be driven by other motivations. Disentangling the rationale behind these motivations might be interesting for TTOs, universities and the industry that could investigate whether the underlying incentives can be leveraged as well in younger researchers. The fact that the willingness of consolidated researchers to patent is not heavily affected by the quality of TTO's services suggest that universities have an important opportunity to reevaluate the services that the TTOs are providing and rearrange the support they should give in order to really boost involvement in protecting new scientific discoveries.

The results of this study also confirm our initial intuition that researchers follow different patterns when deciding to engage in patenting activities. This implies that researchers—and by extension, universities—can combine their resources in various ways in order to safeguard their inventions. The existence of more than one path indicates that universities must identify which one best fits their vision, strategic position and profile of researchers, and based on this, design appropriate policies that facilitate researchers' engagement in this KTT activity.

Finally, another valuable outcome of this work is the instrument to capture researchers' perceptions of the quality delivered by TTOs. This tool is expected to be useful for both university managers and policy makers, and provide opportunities for improvement in the provision of services that boost KTT activities.

## 7. Limitations and future lines of research

While this work makes an original and valuable contribution to the literature, there are a number of limitations that create opportunities for future research. In this sense, a certain limitation refers to the geographical scope of the sample, a Spanish university with a strong technical focus, which prevents generalizing the results to other types of higher education institutions. Therefore, future works might test the model in other universities (e.g., generalist universities, medical schools). Probably, the nature of the research engaged influences the type and the intensity of the KTT activities carried out by faculty members. Also, by expanding the geographical scope of the sample it would be interesting to further examine the effect of the territory (e.g., regional wealth, innovation intensity). Another limitation that open ups opportunities for future works refers to the output. Although KTT activities have been operationalized through a robust metric—number of patents granted in a 5-years period—future studies might consider exploring other KTT indicators. Lastly, given the results obtained, gender differences deserve future attention in order to investigate if women and men follow different patterns with respect engagement in KTT activities.

## Author statement

Erika Sofía Olaya-Escobar: Conceptualization, Data curation, Writing-Original draft preparation. Jasmina Berbegal-Mirabent: Conceptualization, Methodology, Writing-Reviewing and Editing. Inés Alegre: Methodology, Writing-Reviewing and Editing.

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