Technovation 107 (2021) 102287

Contents lists available at ScienceDirect

Technovation

journal homepage: www.elsevier.com/locate/technovation

When do academics patent outside their university? An in-depth case study

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ARTICLE INFO

Keywords:
Academic patents
Technology transfer office
Qualitative
Quantitative
Patent value
Ownership

ABSTRACT

A central theme of university entrepreneurship—including the generation and commercialization of university-invented research—is academic patenting (referring to patenting by university scientists). This study explores organizational-, individual- and patent-level factors and their respective relationship with academic patenting. Based on a thorough investigation of all academic patents (that have at least one university scientist involved) from one of the largest Dutch research universities during the period 2000–2009, and further building on first-hand qualitative and quantitative data, the results show that Technology Transfer Offices (TTOs) are instrumental in generating more academic patents. However, this effect is predominantly manifested by the increase in the number of patents patented under the name (solely or jointly) of the university (*university-owned* patents), far more than the increase in the absolute volume of patents invented by the university (*university-invented* patents). Further, regarding individual academic inventors, our study shows that, in general, male researchers and lead-inventors with higher academic rankings are less likely to abide by the TTOs, resulting in more patents being filed outside the university. Regarding the academic invention, the value of the patent itself does not seem to be related to the choice of the ownership (e.g., university-owned or not) of the patent.

1. Introduction

Academic patenting is a topic that has triggered broad interest of both academics and practitioners. Patents are an important indicator for innovation and the (commercial) impact of scientists (D'Este and Patel 2007; Mowery et al., 2004; Iversen, 2005). The role of universities in new product invention and development is crucial (Wirsich et al., 2016); increasingly, university researchers are participating in academic research that has commercial potential in the form of marketable technologies, products, and services — sometimes resulting in academic patents (Rasmussen et al., 2006). Given the critical role played by academic patenting in new product development and innovation in general, it is important to understand what drives academic patenting. Therefore, researchers have looked into the organizational and individual determinants of academic patenting (e.g., Bercovitz et al., 2001; Walter et al., 2016), the trade-offs between patenting and publishing (e.g., Van Looy et al., 2006, 2011), and the drivers of the commercialization of academic patents (e.g., Giuri et al., 2013; Wu et al., 2015).

Yet, one issue that prevents to develop a clear picture of academic patenting is that many patents produced by academics are not patented under the name of a university (Geuna and Nesta 2006; Lissoni et al., 2013; Thursby et al., 2009; Verspagen 2006) and the institutional affiliation of inventors is often not accurately acknowledged (Murray 2002). As a result, it is estimated that 60–80% of *academic patents* are not *university-owned* patents (i.e., patents that are owned or co-owned by a university) (Lissoni et al. 2008, 2009). Such non-university-owned patents that are based on university inventions are commonly referred to as *university-invented* patents (cf. Crespi et al., 2010; Czarnitzki et al., 2012). Thus, even patents that acknowledge only a commercial institution might actually have an academic origin.

Therefore, multiple researchers have been intrigued by the question of when scientists decide to patent under the name of the university or not (e.g., Aldridge and Audretsch 2010; Fini et al., 2010; Gianiodis et al., 2016; Goel and Göktepe-Hultén 2018; Lawson 2013). Many studies have considered macro-level factors that influence university-ownership, for instance focusing on national legislation such as the Bayh-Dole act and the professor's privilege (e.g., Audretsch and Göktepe-Hultén, 2005; Della Malva et al., 2013; Kenney and Patton 2009; von Proff et al.,

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https://doi.org/10.1016/j.technovation.2021.102287
Received 26 May 2020; Received in revised form 13 April 2021; Accepted 16 April 2021
Available online 24 May 2021

2012). Others have investigated university-level factors, analyzing the effects of differences between universities. These studies have shown that incentives for patenting under the university's name such as revenue shared with the inventor and/or inventor's department have a positive effect on disclosing inventions to the university and filing patents as university-owned (Gianiodis et al., 2016; Walter et al., 2013). Moreover, multiple studies have assessed differences between technology transfer offices (TTOs) at universities and their effect on university patenting (Baglieri et al., 2018; Rothaermel et al., 2007). TTOs are dedicated to identifying research with commercial potential and providing support to exploit these research results (Mowery et al., 2004; Van Burg et al., 2008). Variation in business model, size, competence, age, and experience of a TTO is claimed to be related to differences in university patenting (Baglieri et al., 2018; Goel and Göktepe-Hultén 2018). Yet, despite the popularity and the generally considered benefits of TTOs, to date, results are inconclusive regarding whether the presence of a TTO leads to more university-owned patents or not (Schoen and Buenstorf 2013). This is an important issue, as universities are implementing TTOs and other (patent-related) policies to increase societal impact.

To shed more light on the drivers of university-owned patenting, our study explores micro-level factors inside the university, where existing research has reached contradictory results when it comes to university-ownership of patents. Important differences at the micro-level include inventor characteristics (Thursby et al., 2009) and patent characteristics. For instance, Aldridge and Audretsch (2010), Czarnitzki et al. (2012), and Sterzi (2013) show that academic patents with greater impact and originality are often owned by a company, yet Crespi et al. (2010) do find the opposite. These studies are conducted in different types of organizations with varying sizes and diverse patenting policies, rendering difficulties in generating a fine-grained understanding of the drivers of university ownership of academic patents. This lack of consistent results at the macro-level warrants further in-depth investigation and a search for the underlying mechanisms at the micro-level. We argue that differences at the micro-level *within* universities may explain why someone files patents under the name of the university or rather outside the university.

One reason for the inconsistency in findings regarding university-ownership of academic patents may be empirical. Most studies have used survey data (e.g., Crespi et al., 2010; Gianiodis et al., 2016; Goel and Göktepe-Hultén 2018; Huyghe et al., 2016), which may cover overall patterns, but might suffer from some measurement error due to incorrect answers, backward recalling, or non-response. A more precise strategy is to identify academic patents and to match them with university inventors, and this strategy shows sometimes different results regarding university-ownership of patents (e.g., Aldridge and Audretsch 2010; Czarnitzki et al., 2012; Lissoni et al., 2013; Sterzi 2013; Sterzi et al., 2019). Therefore, using an accurate dataset of a single Dutch public research university, our study focuses on the *within*-organization micro-level factors (inventor characteristics and patent characteristics) and the effect of the TTO on academic patenting. The in-depth analysis is based on detailed data collected in a 10-year timeframe (2000–2009). This period is chosen because in the middle of this period the TTO was established, which helps us to compare the effect of TTO on academic patenting before and after TTO establishment. Using employment data of each inventor and matching that with patent data from the European Patent Office (EPO), we identify inventor-patent matches, resulting in a total list of all patents with university inventors. Our approach helps to further shed light on the micro-level factors, as we can relate university-ownership in academic patenting to both individual characteristics and patent characteristics.

Using patent- and individual-level data, we analyze in-depth what drives inventors to file their patents under the name of the university, or not. We decided that it would allow us for better insights – and give better control for potential confounding institutional differences – to focus on one case and explore the dynamics in this case, in contrast to other studies which have compared macro-level factors aggregated from multiple institutions or based on survey data which might suffer from some measurement error due to incorrect answers, backward recalling, or non-response (e.g., Crespi et al., 2010; Gianiodis et al., 2016; Goel and Göktepe-Hultén 2018; Huyghe et al., 2016). We test the effect of the establishment of the TTO, inventor characteristics, and patent value on university ownership of patents. To complete and sharpen our understanding and interpretations, we complemented our quantitative results with qualitative findings from in-depth interviews conducted with TTO-officers, inventors, and other university staff involved in the patenting process.

This study contributes to the existing literature by providing in-depth insights at the micro-level on what drives academic inventors to file their patents on behalf of their university. Practically, insight into the micro-level factors that influence the number of university-owned patents is crucial for policymakers and university administrators who want to steer the university's output. As typically only university-owned patents are counted as university impact, it is very important to know what drives ownership of all academic patents. We show that the establishment of the TTO does increase the total patent volume, but more importantly, it leads to a significantly larger share of university-owned patents and reduces university-invented patents that are not assigned to the university. Moreover, we show that the more established players such as tenured professors take more freedom to operate and are more likely to file patents outside the university system. Finally, patent value does not appear to lead to strategic behavior in terms of filing patents in- or outside the university.

2. Theoretical background and hypothesis development

Universities play a critical role in the generation and dissemination of knowledge (Mansfield 1998; Narin et al., 1997). Scientific research conducted at universities and knowledge institutes serves as an important input for industrial innovation (Klevorick et al., 1995; Mansfield 1995), and functions as a map for applied research (Fleming and Sorenson 2004). A large part of scientific knowledge is tacit, which makes it difficult to be freely transferred across organizations (Polanyi 1967). Therefore, increasingly academic researchers are involved in the "translation" of basic science, through participating in applied research projects (Cockburn and Henderson 1998) or coming up with research findings that are of high practical relevance and foster innovation (e.g., Mowery et al., 2004). Both activities may result in the generation of academic patents (referring to patents with at least one university inventor).

To strengthen university-industry links, several initiatives have been taken to spur local economic development based on university research. For instance, science parks have been located nearby research university campuses (Vedovello 1997), business incubators and public seed capital funds have been established (Klofsten and Jones-Evans 1996; van Geenhuizen and Soetanto 2009), and bridging institutions are formed that are supposed to link universities to industrial innovation (Mowery et al., 2004; Mowery and Sampat 2005). At the country level, in particular, the passage of the University and Small Business Patent Procedures Act of 1980, also known as the 'Bayh-Dole Act'– providing universities the right to patent and commercialize scientific breakthroughs accomplished with federal funding – has marked an important milestone in the history of university technology transfer, by simplifying and removing many restrictions in the transfer process (Rothaermel et al., 2007; Siegel et al., 2003). Other countries have implemented similar legislation, but with different results (Åstebro et al., 2019). For instance, in Germany, the 'professor's privilege' was abolished, granting the university instead of the inventor the ownership over inventions. This did not lead to an increase in university patents overall, but it did increase university-owned patents (von Proff et al., 2012).

Despite such efforts to strengthen university-industry links and to increase the number of university patents, a large share of academic

patents is however patented solely on behalf of companies. Such university-invented (in contrast to university-owned) patents as such are typically not accredited as university impact as they are not recognized as academic patents (Gianiodis et al., 2016; Markman et al., 2008). This may be a critical issue because it makes it much more difficult to measure the true effect of academic involvement in practical research as well as to assess university-industry linkages. For universities, patents also serve as signals to potential stakeholders to obtain access to funding and other useful resources (Veer and Jell 2012). Universities are increasingly evaluated on their contribution to innovation (Perkmann et al., 2013) with an intention to gain a share of the commercial revenues of these inventions (Geuna and Nesta 2006). Therefore, it is crucial to understand what drives the ownership of academic patents.

As multiple studies have focused on macro-level factors on university patenting and university-ownership of patents such as regulation and differences between universities (e.g., Goel and Göktepe-Hultén 2018; Thursby et al., 2009; Walter et al., 2013, 2016), we shift focus to micro-level factors (organizational-, inventor- and patent-level) inside the university that may influence ownership of academic patents. In Europe, where our study is conducted, most universities have substantial autonomy in establishing rules and regulations about how to deal with inventions and patents (Geuna and Rossi 2011). Rules about sharing the revenue of licensing to the inventor and/or inventor's department appear to have a positive effect on making patents university-owned (Gianiodis et al., 2016; Walter et al., 2013), while they do not seem to affect the overall number of academic patents (Arqué-Castells et al., 2016). Moreover, universities collaborate with industry through multiple channels, such as collaborative research, contract research, and multiple forms of consulting (e.g., Bekkers and Bodas Freitas 2008; Perkmann et al., 2013; Perkmann and Walsh 2008). Such arrangements, in particular in the form of contract and collaborative research, negatively (Stevens et al., 2011) influence university-ownership of inventions, as often companies aim to get the commercial rights on the research they (partly) funded, which might lead to fewer university-owned patents (Belderbos et al., 2014; Crespi et al., 2010).

Focusing on university infrastructure, multiple researchers have looked into the effect of TTOs on patenting behavior in universities (see for a review of TTO literature Hayter et al., 2018; Huyghe et al., 2016). TTO experience and TTO size are related to the number of patents filed and licensed by a university (Carlsson and Fridh 2002; Zhou and Tang 2020) and these factors are sometimes also associated with the revenue generated by these patents (e.g., Kolympiris and Klein 2017; Markman et al., 2005). In general, researchers who receive support from their TTO are more likely to file a patent (Sellenthin 2009). Yet, even though the presence of a TTO appears to influence university-ownership of patents (Sterzi et al., 2019), in particular in the case of more autonomous TTOs (Markman et al., 2008), it is clear that not all researchers patent via their research institute's TTOs, for multiple reasons. These reasons include unawareness of the TTO (Huyghe et al., 2016), perceived unwillingness or ineffectiveness of the TTO to patent their finding (Aldridge and Audretsch 2010; O'Kane 2018), and overt opportunism in that researchers can gain more by patenting without TTO (and university) involvement (Gianiodis et al., 2016).

Next to university infrastructure, also shared norms at the university-level influence patenting behavior. Such norms refer to taken-for-granted beliefs and practices that are shared in a group or organization, and that influence acceptable behavior (Hayter and Feeney 2016). Patenting norms, shared in one organization, seem to have a positive effect on overall patenting and patenting inside the university (Hayter and Feeney 2016; Walter et al., 2016), but patenting capabilities and publication norms appear to have no effect (Walter et al., 2016).

At the individual level, faculty rank and tenure can influence the ownership of academic patents. Bercovitz and Feldman (2008) found that some people only adhere symbolically to the official rules in a research institute, while others substantively identify with the rules and are also more influenced by the norms in their peer group. Some studies have looked into these individual differences, but the results are inconclusive. Some have found that higher-ranked academics (i.e., tenured staff and full professors) are less likely to file patents outside the university (Hayter and Feeney 2016; Sterzi et al., 2019; Thursby et al., 2009). At the same time, others found that tenured academics are more likely to file patents outside the university (Crespi et al., 2010; Gianiodis et al., 2016). Stevens et al. (2011) have pointed at the fact that some universities have added commercialization considerations into account as a tenure criterion, which might lead to more patenting by people who are about to get tenure. In sum, studies till now did not find clear and consistent results of the impact of faculty rank.

Finally, studies have looked into how patent characteristics influence university-ownership of these patents. An obvious argument is that patents that are the result of company-funded research are more likely to be owned by companies (Belderbos et al., 2014). Nevertheless, there is no clear effect of such collaboration on the assignment of the patent ownership, except for the case of university spin-off firms and other forms of entrepreneurial collaboration (Gianiodis et al., 2016; Lawson 2013; Markman et al., 2008). Importantly, some studies have found that the (expected) short-term value of patents is related to the tendency to file patents outside the university (Aldridge and Audretsch 2010; Gianiodis et al., 2016; Markman et al., 2008), while more basic or fundamental patents, with later forward cites are more likely to be assigned to universities (Czarnitzki et al., 2012; Sterzi 2013; Thursby et al., 2009). Overall, patent characteristics may influence the decision-making of individuals, companies, and universities.

In this study, we analyze one of the largest public research universities in The Netherlands. Therefore, we can consider the national context as a constant, as well as the majority of the university-level factors. Focusing on the micro-level factors related to university patenting, we aim to deepen our understanding of three aspects: the effect of the TTO, the effect of an individual's academic rank, and the effect of patent value. Assessing the effect of the TTO, even in a single case, is possible as we focus on a 10-year timeframe that includes the moment when the TTO was established. Such a focus on a single university brings the unique advantage that these different effects can be established while the context remains constant. Moreover, where current studies have either focused on characteristics measured via surveys such as university-level characteristics (e.g., Goel and Göktepe-Hultén 2018; Markman et al., 2008; Walter et al., 2016) and inventor characteristics (e.g., Hayter and Feeney 2016; Sterzi et al., 2019; Thursby et al., 2009), or rather patent-characteristics based on patent data (e.g., Czarnitzki et al., 2012; Lissoni et al., 2013; Sterzi 2013), this study can assess these different aspects at the same time.

2.1. Technology transfer offices and academic patent ownership

Our first hypothesis concerns the effect that a TTO has on whether patents are filed 'inside' or 'outside' the university system. In general, the assumption is that TTOs will enhance universities to transfer technology, and often policymakers expect that this helps universities to reap part of the commercial benefits of these technologies (Baglieri et al., 2018; Decter et al., 2007; Fitzgerald and Cunningham 2016). TTOs are thus expected to increase the share of university-owned patents (Carlsson and Fridh 2002; Sterzi 2013). Yet, despite these general assumptions about the function and effect of a TTO, research on the actual effect of TTOs is inconclusive. For instance, in Italy, Sterzi et al. (2019) did not find an effect of the presence of a TTO on the share of university-owned patents. Similarly, Aldridge and Audretsch (2010) analyzed the patenting behavior of research grant awardees in assigning their patents to their research institute and found that TTO size did not affect whether patents were filed under the name of the research institute. Yet, in France there appears to be a positive effect (Della Malva et al., 2013). The absence of an effect might be due to inventors who avoid the TTO's inference (Thursby et al., 2009) or who are unaware of the role of the TTO (Huyghe et al., 2016).

We hypothesize a positive effect of introducing a TTO at a university, in particular for the number of university-owned patents, for the following two reasons. First, university researchers are trained in rather different ways compared to commercial managers or patent attorneys, and often may not possess the acumen for identifying the potential patentability of their inventions, nor the skills and specific experiences required for patenting and technology transfer (which in many cases involve lawyers and administrative staff). Further, patenting may consume a considerable amount of time and energy which has to be taken from the research time of university researchers. Therefore, introducing a TTO that has general expertise in patenting and patent management reduces that burden for scientists (Siegel et al., 2003), thus making it easier to patent their inventions and, as a result, contributes to an increase in the overall volume of academic patents.

Second, in most universities, academic researchers are evaluated based on a different set of criteria (e.g., publications, teaching, research grants) rather than the number of academic patents they are associated with, which may undermine their motivation to file patents. Rather than doing it themselves, they might give the invention away or sell the property rights to a firm or a different third party. The establishment of a TTO as an important unit in the university's institutional environment may therefore help to increase the awareness of academic researchers about academic patenting under the name of the university, and provide them with additional benefits, such as recognition and even monetary incentives, which, in turn, contribute to the increase of university-owned patents. Taken together, we hypothesize:

H1. The establishment of a technology transfer office (TTO) in the university leads to an increase in patents that are assigned to the university.

2.2. Academic rank and academic patent ownership

At the individual level, we focus on the effect of the rank of the individual inventor in the university, capturing the effect of the inventor's career stage. In line with the literature, we see ranks in the university as positional differences in the university employment structure, ranging from PhD-student (on the lower side) through tenure to full professor (on the higher side). A few studies have considered rank differences between individual inventors in relationship to patenting inside or outside the university. Thursby et al. (2009) found that higher-ranked US researchers (in their case: inventors with tenure in 1993) are less likely to file patents outside the university, and Sterzi et al. (2019) found that also in Italy full professors' patents are more likely to be university-owned. Similarly, based on survey data Hayter and Feeney (2016) found a marginally significant effect of university rank on patenting under the name of the university. Yet, other studies found the opposite, namely that higher-ranked academics are more likely to file patents outside the university (Crespi et al., 2010; Gianiodis et al., 2016).

Based on theoretical arguments, we argue that the higher the academic rank of the inventor, the more likely he or she will opt for patenting outside the university, for the following reasons. First, higher formal positions are related to greater autonomy in work, as well as a larger amount and better quality of relations and resources within the organization (Allison 1971; Pettigrew 1973). People with higher positional status can shape and mold existing norms and practices (Bercovitz and Feldman 2008; DiMaggio 1988) without fearing to be "punished" or thrown out of the organizational rank. This may result in more "bold" patenting behavior, such as patenting outside the university even though shared norms or official rules prescribe differently. As the higher-ranked academics have established their legitimacy and reputation in the organization, and shaped the institutionalized norms themselves, they can also afford to deviate from these practices because they were the ones who set the rules (Colyvas and Powell 2007). Second, higher-ranked academics are also more central in their organizations, and thus have the benefits that come with centrality such as more power and privileges (Hackman 1985; Ibarra 1993). Thus, it is easier for them to organize their own ways of dealing with inventions, compared to people who are less central. Overall, this leads towards the following hypothesis:

H2. The higher the academic rank of the inventor, the more likely the inventor will file the patent outside the university.

2.3. Patent value and academic patent ownership

Besides organizational- and individual characteristics, patent-level factors may play an important role in determining the ownership of these patents. Higher value patents (particularly measured by the number of forward citations) are related to filing outside the university (Czarnitzki et al., 2012; Gianiodis et al., 2016; Markman et al., 2008; Schoen and Buenstorf 2013; Thursby et al., 2009). Nevertheless, others did not find a relationship between estimated patent value and filing patents as university-invented patents (i.e., without the university as assignee) (Crespi et al., 2010). Given the overall pattern in these studies, we suppose that academics' patenting behavior is also contingent on the value of the patent itself.

First, patents represent legal protection of an invention in certain geographical markets and are directly linked to the commercial potential of the invention (Teece 1986). Therefore, inventions that are of higher (expected) value are more likely to attract external (commercial) sponsors who are willing to take care of the patent filing and maintenance process and the costs involved, in exchange for the ownership of the invention. Such commercial parties can offer conditions and support that TTOs – if existing – often cannot meet, for instance in maintaining and defending a patent. They may even give substantial incentives or compensation to the university inventor (or his/her research group) that university TTOs are unable to match with (or they simply possess more bargaining power vis-à-vis the TTO). This may be particularly salient in cases where the objectives of the TTOs are not strictly enforced on the academics (Rothaermel et al., 2007).

Second, higher value inventions also enable their inventors to develop more "dynamic" careers both in and outside a university and thus are more likely to enjoy a higher level of employee mobility in the form of part-time or full-time transitions to industry positions. A high-quality patent can easily provide a stepping stone for a good position in the industry, as empirical evidence suggests (e.g., Almeida and Kogut 1999; L. G. Zucker et al., 2002). The utility incentives enabled by the long protection period of patents (usually 18 years after they are granted) and the barriers brought by the complex legal issues regarding the division of the ownership may further make it less desirable for the inventor to patent under the name of the university. As a result, these inventors may be more active in searching for potential alternatives to appropriate (long-term) value from their invention outside the university, which may result in a lower percentage of university-owned patents.

Third, from a cost perspective, there are not only potential benefits, but also expected cost (in terms of time and resources) associated with patent filing. Therefore, if the patent is of low value, the expected cost of patenting may exceed the expected benefit for the university. Thus, it may then be financially more attractive for the university to give the invention away, instead of actively claiming ownership of it. Taken together, we hypothesize that:

H3. The higher the value of the invention, the more likely the inventor will file the patent outside the university.

3. Methods

3.1. Study setting and data collection

To test the effect of these organizational-, individual- and patent-

level factors, with the aim to explore underlying, micro-level mechanisms, we conduct an in-depth study of one of the largest public research universities in The Netherlands. This single case allowed for a unique combination of analysis of longitudinal patent data with qualitative insights from relevant informants such as inventors, deans, and TTO officers. This mixed-methods approach has the advantage that the quantitative analysis can test the key patterns and subsequently, the qualitative analysis can further validate as well as inform understanding of the mechanisms driving these patterns (see Creswell, 2010; Teddlie and Tashakkori, 2008). Moreover, by focusing on the patterns at a single university we avoid the confounding effect of potential unobserved institutional heterogeneity due to differences between institutions (see e.g., Meyer et al., 2005) that may have played a role in large-scale studies involving multiple universities.

The Netherlands has implemented Bayh-Dole-type legislation for about three decades (Bekkers et al., 2006), and most universities have established technology transfer offices since the end of the 1990s (Van Burg et al., 2008). Against this national background, our choice of one of the largest Dutch research universities forms an interesting case as here the TTO was established in 2006, which is quite late compared to the other universities in The Netherlands. Thus, the national-level regulations were already well established, but the implementation at the university was lagging, making this case interesting to test the effect of the establishment of a TTO. This university has the rule that the revenues from patents are shared equally between the university, the department, and the individual inventor.

To gather patent and inventor data from this university, we got access to the employment records of all of its researchers employed (including the separate medical school) during the period 2000–2009, which enabled us to collect patents before and after the "treatment" (the establishment of the TTO). Our dataset included the first name, last name, official name, initials, prefixes, gender, date of birth, department, function, and discharge date (if applicable) of the academic inventors. Following other studies (e.g., Aldridge and Audretsch 2010; Czarnitzki et al., 2012; Lissoni et al., 2013; (Meyer et al., 2005) Sterzi 2013; Sterzi et al., 2019), the names of university employees were matched with the patent records of the European Patent Office (EPO). Name-matches were carefully checked, sometimes by contacting the inventor involved, to avoid misallocation of patents to different inventors with the same name. Apart from that, we also checked whether the patent was actually filed when the inventor was employed at the university (and not before or after). All patents that belong to one patent-family were taken together. This led to 123 patents matched and validated with their respective inventor and patent information. Further, we carefully checked all the patents with the earliest priority date in their patent family, examined the original patent file documents, and assembled several key indicators about the value of the patent (i.e., number of claims, number of patents in the patent family, forward citations, backward citations, etc.) from these original documents.

To further understand our quantitative results, we performed in-depth interviews with eleven informants. These informants held relevant positions at the TTO and in the university. Our interviewees span a wide spectrum and include two directors of the TTO, three heads of different departments and faculties, two operational directors of faculties, one program manager at the university level, one higher-ranked researcher, and two lower-ranked researchers. Some of the respondents had patented themselves, others not. A semi-structured interview protocol was used that covered the practices and experiences with patenting in this university. All interviews were recorded, fully transcribed and subsequently analyzed using open coding procedures focused on identifying the main mechanisms underlying the relationships that we hypothesized.

3.2. Analytical approach

For our analysis, we employed a binary logistic regression model, as we can only observe whether or not the patent is filed under the university's name, and thus our dependent variable is a 0/1 variable (1 represents if the patent was filed under the university's name and 0 otherwise). In this model, y equals to 1 only when an unobserved, continuous variable y* exceeds a threshold value μ that is also unobserved. The model is specified as follows:

$$y_i = \begin{cases} 1 & if\ y_i^* > \mu \\ 0 & if\ y_i^* \leq \mu \end{cases}$$

For this paper, we assume that there exists a linear relationship between y^*, the vector of observed covariates x_i, and the residual ε_i, thus:

$$y_i^* = \alpha\, x_i + \varepsilon_i$$

and assume that the residual variance follows a logistic distribution and a fixed variance, which then follows

$$y_i = \log\left(\frac{p_i}{1-p_i}\right) = \beta\, x_i$$

where $\beta = \frac{\alpha}{\sigma}$ (σ is the standard deviation of ε_i).

3.3. Variable descriptions

3.3.1. Dependent variable

3.3.1.1. University ownership. We use a dummy variable with the value "1" denoting the academic patent is solely or jointly owned by the university, and the value "0" if otherwise.

3.3.2. Independent variables

3.3.2.1. Establishment of the TTO. This is a dummy variable with the value "0" indicating the TTO was not yet established in the year of patenting of the focal patent (before 2006), and the value "1" if the TTO was already established in the year of patenting of the focal patent (in or after 2006).

3.3.2.2. Academic rank. The academic rank of the inventor is represented by a categorical variable with five different values, with the values of the variable corresponding to the order of the academic rank. Research assistants who do not hold, nor are in the process of pursuing a Ph.D. degree are coded as "1", Ph.D students are coded as "2", junior researchers (post-docs and untenured assistant professors) are coded as "3", senior researchers (tenured assistant professors and associate professors) are coded as "4". Finally, full professors and professors with high positions in the organization (i.e., deans) are coded as "5".[1]

3.3.2.3. Patent value. In this study, we use several measurements to capture the value of the patent. We created a variable *Triad patent*, coded as "1" if the patent is filed at all three major international patent offices, namely: USPTO (United States Patent and Trade Office), EPO (European Patent Office), and JPO (Japan Patent Office), and "0" otherwise. As it may not be that common for a patent to file at all three international patent offices, we also created a variable *Any two of triad patent* (0/1) to capture the value of the patent if filed at any two of the three major patent offices.

Besides "Triad patent", we created two other variables to measure the originality and the value of the patent. First, *Originality* of the patent

[1] In cases of patents with more than one inventor from our focal university, each individual inventor appears as a different record in the dataset. Their individual characteristics (academic rank, age, gender, faculty and faculty budget) are associated with each of them as an individual attribute rather than a group average. The error terms are clustered at the team/patent level.

is defined as

$$Originality_i = 1 - \sum_j^{n_i} S_{ij}^2$$

where S_{ij} denotes the percentage of citations made by patent i that belongs to patent class j, out of n_i patent classes, where the sum is the Herfindahl concentration index (Hall et al., 2001; Trajtenberg et al., 1997). Therefore, if a patent cites previous patents that belong to a narrow set of technologies, the originality score will be low, whereas citing patenting in a wide range of fields would render a high score (Hall et al., 2001). For each of the patents in our sample, we calculated its originality score based on this formula. Second, *Number of forward citations* captures the value and influence of the patent, as the more the focal patent is cited by other patents, the more valuable and influential it probably is (Harhoff et al., 2003; Trajtenberg et al., 1997).

Finally, we created *Number of claims* by measuring the number of claims as stated on the patent document to capture the level of complexity of the project (adapted from Du et al., 2014).

3.3.3. Control variables

In this study, we further controlled extensively for several factors to rule out potential confounding effects.

3.3.3.1. Number of inventors. The size of the research team that generated the patent is measured by the number of inventors of the patent. The size of the team of inventors is used as a proxy for the resources and capacity of the research project.

3.3.3.2. Percentage of university researchers. Team size alone may not be sufficient to predict the likelihood of university ownership. Based on our investigation into the original patent files, we noticed that sometimes there was only one university researcher involved in the invention, while other times there were more academics associated with one invention. We suppose inventions that have multiple academics involved may have a higher likelihood to be patented under the university's name, not only because of "peer pressure", but it may also symbolize a relatively large share of university involvement. Therefore, we created the variable *Percentage of university researchers*. In our sample, for 47 patents (38.21%) there is more than one university researcher involved. We suppose that the larger part the university researchers take in a research project, the more likely the resulting invention will be patented under the university's name.

3.3.3.3. Gender. Prior studies showed that gender plays an important role in patenting activities (Ding et al., 2006). In this study, a dummy variable with the value "1" indicating the academic researcher is male, and "0" if female.

3.3.3.4. Age. This is a categorical variable comprised of five categories to denote the age of the academic inventor. Among which "1" means the inventor is aged between 20 and 29 at the time of patent filing, "2" refers to the age group 30–39, "3" denotes 40–49, "4" refers to 50–59, and finally, "5" denotes the age group 60–69.

3.3.3.5. Company applicant. This is a dummy variable that takes the value "1" if the patent applicant involves a company, and the value "0" if otherwise. Company applicant may indicate contract research or (at least) the involvement of industry, for instance in the form of joint research, which, in turn, may be negatively related to university ownership of the academic patent.

3.3.3.6. Total number of patents per year. This measures the annual total number of patents in which at least one university researcher is involved, regardless of the ownership of the patent. With this variable, we aim to capture the differences at the university level related to the changes (if any) in terms of research budget, university policy, and other university-level changes, if any.

3.3.3.7. Allocated faculty budget. This variable is measured as the annual budget allocated to each faculty in the university (in million euros). It captures resource endowment to the faculty, as well as possible changes in resource allocation in each faculty.

3.3.3.8. Faculty dummies. Research outcome and patenting behavior may differ by the broad discipline of the research undertaken. Therefore, we further included a series of dummy variables at the faculty level to denote in which faculty the academic patent was generated. In general, seven faculties have contributed to at least one academic patent in our observation period. These are: the University Medical Centre (named Faculty of Medicine until 2001) (63.41%), Faculty of Earth and Life Sciences (8.94%), Faculty of Sciences (17.07%), Faculty of Dentistry (6.50%), Faculty of Kinesiology (2.44%), Faculty of Chemistry (which became part of the Faculty of Sciences since 2001) (0.81%), and Faculty of Biology (which became part of the Faculty of Earth and Life Sciences since 2001) (0.81%). As the last three faculties are very small in the number of patents and were reorganized, they are combined into a broader group— the 'rest category'.

3.3.3.9. Year dummies. To control for the possible confounding effect of patent filing at the university across different years, we further included a series of year dummies in the analyses. Because the number of patent filings is in general rather scant when being distributed to each year, we grouped the years included in our analysis into four periods: 2000–2002; 2003–2005; 2006–2008; 2009–2010.

4. Descriptive statistics

Descriptive statistics and correlations among the variables are provided in Table 1. In general, slightly less than half of the academic patents are university-owned (solely or jointly) (42.3%), and the remaining ones are either owned by a company or another organization. In our sample, about half of the patents (64 patents; 52.0%) were filed before the TTO was established, while the other half (59 patents; 48.0%) were patented after the establishment of the TTO. The almost equal distribution of patents gives us a preferred setting to study and compare the effect of TTO on academic patenting behavior. On average, 3.5 individual inventors are associated with one academic patent, with the percentage of university researchers on each patent being 54.8%. If more than one university researcher is contributing to the same academic patent, the information of the lead-researcher is used.[2] The majority of these university researchers are male (on average 83.7%), mainly aged between 40-49 and 50–59. The academic ranks of these university researchers are generally high, with the majority being associate professors or higher. 44.7% of the patents are with a *company applicant*, which implies strong involvement of the industry. Of all academic patents, 17.1% are qualified as "Triad patents". In our sample, an academic patent has on average 24.4 claims, cited 4.1 prior documents, and is cited by 3.0 other inventions. Further, there are on average 6.4 patents in a patent family. To control for university-wide policies and research budget, we included the annual total number of academic patents that university researchers are involved in, which averages 14.0 patents per year. A further check of the data shows that, among the 123 academic patents, 52 patents have the university as a (co-)applicant (42.3%). Of these patents, 17 patents were solely assigned to the university (13.8%); two patents were co-owned with a company (1.6%); five patents were co-owned by the university, a company, and individual

[2] In our robustness checks, we expanded the data and included all academic inventors of the patent, which produced similar results.

Table 1
Descriptive statistics and correlations.

	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. University ownership	0.41	0.49	1.00																
2. Establishment of TTO	0.48	0.50	0.42	1.00															
3. Academic rank	3.83	1.11	−0.12	−0.28	1.00														
4. Triad patent	0.17	0.37	−0.11	−0.13	−0.10	1.00													
5. Any two of triad patent	0.39	0.49	−0.02	−0.07	−0.12	0.55	1.00												
6. Number of inventors	3.46	1.93	−0.11	−0.04	0.13	−0.10	0.07	1.00											
7. Percentage of university researchers	0.54	0.30	0.30	0.09	−0.09	0.09	0.03	−0.61	1.00										
8. Gender	0.84	0.37	−0.26	−0.19	0.21	0.02	0.04	−0.06	0.05	1.00									
9. Age	3.68	1.09	−0.17	−0.27	0.67	−0.04	−0.15	0.01	0.02	0.33	1.00								
10. Number in the patent family	6.30	7.27	−0.14	−0.16	−0.07	0.44	0.43	0.07	−0.11	0.04	−0.05	1.00							
11. Company applicant	0.45	0.50	−0.49	−0.11	−0.09	0.15	0.21	0.19	−0.30	−0.09	0.02	0.22	1.00						
12. Total patents per year	14.15	4.85	0.25	0.63	−0.24	−0.10	0.10	−0.10	0.12	−0.10	−0.23	−0.02	−0.14	1.00					
13. Allocated faculty budget	63.44	38.75	0.10	−0.03	−0.13	−0.07	−0.09	−0.13	0.23	−0.02	0.01	−0.10	−0.16	0.03	1.00				
14. Originality	0.30	0.34	0.03	0.14	−0.09	−0.06	0.07	−0.05	0.05	0.03	0.04	−0.11	0.11	0.07	−0.10	1.00			
15. Forward citations (5 years)	2.13	4.31	−0.04	0.00	−0.01	−0.16	−0.04	−0.12	0.05	0.17	0.04	−0.10	0.05	0.09	0.03	0.06	1.00		
16. Forward citations (10 years)	3.35	6.16	−0.05	0.01	−0.02	−0.16	−0.04	−0.10	0.06	0.19	0.03	−0.10	0.04	0.11	0.02	0.06	0.95	1.00	
17. Number of cited documents	3.86	4.11	0.02	0.17	0.04	−0.15	−0.06	−0.01	−0.07	0.02	0.08	−0.14	0.05	0.10	−0.09	0.59	0.14	0.11	1.00

(N = 123).

inventors (4.1%); five patents were co-owned with an organization and individual inventors (4.1%); 22 patents were co-owned between the university and individual(s) (17.89%); and the ownership of one patent was shared between the university, another organization, a company and individual inventors (0.8%). Apart from these 52 university-(co-) owned patents, 71 patents were filed under other names rather than the university (57.7%). Of these patents, 19 patents were solely patented under a company's name (15.5%); 25 patents were co-owned by a company and individual inventors (20.3%); and, finally, 25 patents are neither owned by the university, nor a company, but are patented under the name of a different organization only (5 patents, 4.1%), an organization and individual inventors (15 patents, 12.2%), under the name of the individual inventors themselves (5 patents, 4.1%), or co-owned by company, organization, and individual inventors (2 patents, 1.6%). Among the patents that have a company applicant (54 patents, 43.9%), only eight of them (6.5%) are also with the university as a co-applicant. In contrast, the percentage of university-owned patents (solely, 17 patents, 13.8%), or jointly with individual inventors (22 patents, 17.9%), or with a different type of organization (5 patents, 4.1%), is significantly higher when the applicant does not involve a company. Hence, it seems that industry participation may significantly reduce the likelihood of university ownership of an academic patent.

Regarding the role of the TTO, in general, Fig. 1 shows strong increases both in terms of the absolute volume of *university-invented* patents, as well as the volume of *university-owned* patents since the TTO's establishment in 2006. Further, it is clear that the effect of TTO is mainly manifested on the university-owned patents, much more compared to university-invented patents (Fig. 1). For an overview of detailed patent ownership types, please refer to Table 2.

For graphs with a more detailed breakdown by academic ownership of each of the key variables, please see Figs. 2–10 in Appendix A.

5. Findings

The results of the regression analyses are shown in Table 3. Our analysis is at the patent-inventor level. Model 1 is the baseline model that includes only the control variables. The coefficient estimates for the controls indicate that the project size (measured by the number of inventors) does not seem to affect university ownership of a patent. However, the larger the percentage of university researchers involved in an invention (with inventor teams sometimes also including company-inventors), the more likely it is patented under the university's name. The significant and negative coefficient of gender (female coded as "0" while male is coded as "1") indicates that, compared to their female counterparts, male academic inventors are much more likely to bypass the university and file their inventions outside the university. Interestingly, the age of the inventor does not seem to be consistently linked to the likelihood of university-owned patents, which may imply a rather weak, if any, association between age and academic patenting behavior. The involvement of a company applicant seems to be a strong and negative predictor of university-ownership of patents, which may be explained by the relatively weaker bargaining power of the university to claim ownership of the patent when their industrial counterpart is also involved in the patent. The volume of the total academic patents of the university (both *university-invented* and *university-owned*) does not seem to affect the *university-ownership* of the patent. Moreover, the size of the patent family and the budget of the faculty both do not seem to affect the ownership of the academic patent. Finally, the faculty dummies and the year dummies are jointly significant, thus capturing differences across faculties and years in terms of academic patenting behavior.

The *Establishment of TTO* variable is added in Model 2. The coefficient of this variable is positive and highly significant. This indicates that ceteris paribus, the establishment of the TTO has a strong and significant impact on university-owned (solely or jointly) academic patents (Model 2). This is in line with Hypothesis 1, which posits that TTOs play an overall positive role in facilitating the increase in the number of

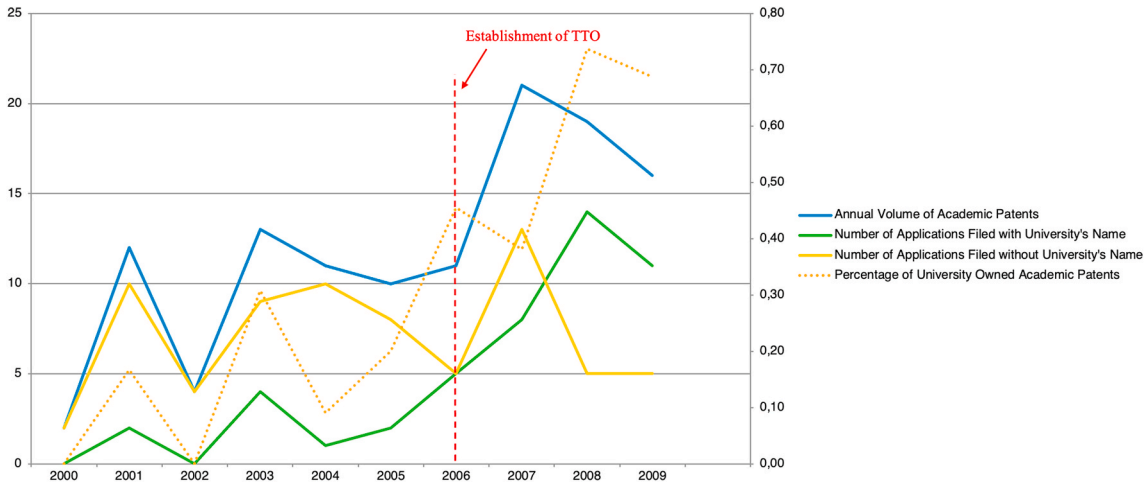

Fig. 1. The effect of TTO on academic patenting and university ownership of academic patents.

Table 2
Patent ownership types.

Broad type	Patent ownership type	Number of patents
University-owned	Solely university-owned	17
	University & organization & individual(s)	5
	University & individual(s)	22
Company-owned	Solely company-owned	19
	Company & organization & individual(s)	2
	Company & individual(s)	25
Hybrid	University & company	2
	University & company & individual(s)	5
	University & organization & company & individual(s)	1
Other	Solely organization-owned	5
	Organization & individual(s)	15
	Individual(s)	5
	Total	123

university-owned patents. In addition, Fig. 1 shows that not only the number of university-owned but also the overall number of academic patents increases. Fig. 1 shows an interesting peek in 2007 and a 'drop' in 2008 and 2009, which can be interpreted as the effect of the establishment of TTO on patent filings. According to one of the TTO managers, one of the first tasks of the TTO was to "where possible … repair those filings", pointing at inventions that were in the process of being patented outside the university. As a consequence of those filings by the TTO in 2006, there is a peak in 2007 and a smaller one in 2008; in 2009 the number is back to 'normal'.

This finding is also supported by qualitative evidence from the interviews. In general, the interview data indicate that scientists and university managers are aware that quite some inventions are filed outside the university. A faculty's operational director stated: "There is a lot that happens, bypassing the system inside. Of course, we don't want that. Clearly, the intellectual property is owned by the employer, so you don't want that it leaks away via the backdoor. And of course, we also want to be able to show our impact in factsheets, which is what we are doing." A TTO manager reflected: "Before 2006, so before the TTO, it was more like a case-by-case evaluation. … It looked like the medical school was more aware of patents than the other faculties. As soon as the TTO was established in 2006, we discussed filings outside the university with involved individuals, departments, and faculties, and where possible we tried to repair those filings." These interview findings confirm the change brought about by the introduction of the TTO. As one department head stated: "Since my start at the university I am involved in this, first predominantly through contract research and shortly after that regarding patents. But patenting was always done in collaboration with the industry, the industry was responsible for the patents." Now, since the establishment of the TTO, this situation (i.e., company ownership of the patents) has changed: "In each of our projects now the IP rights will be distributed 50/50 and only in rare occasions the IP rights will belong only to the company. That's now only the case if we really want to do the research and it depends on the financial conditions."

Thus, interview data suggest that, in the past, patenting was not well supported or even considered at the university, and therefore regularly patents were given away to companies. The establishment of the TTO, probably in line with an overall trend to be more focused on university IP, impacted the current preference for contract research, which is that the patent should be assigned to both the university and the company. Yet, despite this preferential IP strategy, interviewees acknowledge that there are also cases in which inventors willingly bypass the TTO, as one department head stated: "Sometimes I overhear researchers saying: If I go to TTO, I will … lose part of my autonomy … but also part of my money, as a major part does not go to me but to TTO." At the same time, as a TTO manager admits, sometimes inventors or companies get the possibility to own university IP: "In several cases, we have granted the inventor the patent, as a deliberate choice. At the same time, it is not the preferred option as it could give an incentive to underestimate the value of the invention or to reduced collaboration [with TTO]."

In Model 3, the variable *Academic rank* is added to the regression. Some of our analysis results confirm the negative effect[3] of academic rank on university ownership of the academic patent, which partially supports Hypothesis 2. Hypothesis 2 stated that the higher the academic rank of the (lead-)inventor, the more likely he/she will file the patent outside the university. The interview data shed more light on these highly-ranked individuals who bypass the university system. First, some professors admit that they have granted companies the right to patent their inventions, because it was too cumbersome to deal with the patenting procedure at the university or because the company paid for the patent or the research that led to the patent. As one professor stated: "We have sold these [patents] to the industry. … An external partner has written the patents, we delivered the content, but patent specialists of these companies filed the patents." Another interviewee stated: "When I consider the TTO, they do things too broadly and as a result lack sufficient expertise to say for each domain: you can patent this, and you can't do that. The university is so broad and diversified, it is nearly impossible to do that, and that requires experts on those positions. It may be

[3] In our robustness checks, however, this effect diminished when taking into account the gender of all academic inventors in the team.

Table 3
Binary logistic regression on university ownership of the academic patent.

Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)
Establishment of TTO		2.108**				1.933**	1.958**
		(0.874)				(0.919)	(0.886)
Academic rank			−0.773*			−0.691	−0.799*
			(0.447)			(0.450)	(0.455)
Triad patent				−0.137		−0.240	
				(0.649)		(0.598)	
Any two of triad patent					1.575*		1.662*
					(0.954)		(0.949)
Number of inventors	0.108	0.155	0.142	0.107	0.0658	0.199	0.150
	(0.181)	(0.172)	(0.191)	(0.180)	(0.198)	(0.189)	(0.210)
Percentage university researchers	3.172**	3.101**	3.088**	3.203**	2.599*	3.187**	2.587*
	(1.391)	(1.448)	(1.360)	(1.424)	(1.391)	(1.509)	(1.442)
Gender	−2.888***	−3.186***	−3.116***	−2.869***	−3.125***	−3.319***	−3.725***
	(0.890)	(0.895)	(0.840)	(0.883)	(0.850)	(0.863)	(0.858)
Age	0.296	0.246	0.801**	0.296	0.313	0.697**	0.822**
	(0.327)	(0.322)	(0.323)	(0.327)	(0.325)	(0.308)	(0.342)
Patent family size	−0.0187	0.0113	−0.0172	−0.0140	−0.139	0.00745	−0.0918
	(0.0679)	(0.0377)	(0.0514)	(0.0704)	(0.124)	(0.0335)	(0.113)
Company applicant	−3.668***	−4.055***	−4.003***	−3.665***	−3.984***	−4.256***	−4.688***
	(0.881)	(0.881)	(0.895)	(0.881)	(0.836)	(0.887)	(0.871)
Total patents per year	−0.0428	−0.135	−0.0432	−0.0457	−0.0546	−0.128	−0.140
	(0.0937)	(0.0958)	(0.0915)	(0.0950)	(0.0862)	(0.0971)	(0.0946)
Allocated faculty budget	0.00421	−0.00155	0.00500	0.00391	0.00787	−0.00152	0.00257
	(0.0153)	(0.0151)	(0.0163)	(0.0154)	(0.0158)	(0.0163)	(0.0167)
Faculty dummies	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Year dummies	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Constant	−12.17***	−12.90***	−10.67***	−12.14***	−10.22***	−11.62***	−10.03***
	(2.762)	(2.667)	(2.842)	(2.767)	(2.577)	(2.824)	(2.674)
Observations	123	123	123	123	123	123	123
Log Likelihood	−40.88	−39.45	−39.30	−40.87	−39.50	−38.22	−36.67
Pseudo. R-squared	0.512	0.529	0.531	0.512	0.529	0.544	0.562

Robust standard errors in parentheses.
***p < 0.01. **p < 0.05. *p < 0.1.

possible with help from externals, but hiring an external expert is very expensive." Thus, it seems that higher-ranked researchers feel relatively at ease with giving critique to the university service and with bypassing the institutional rules.

Second, the position, experience, and centrality of researchers with higher ranks also provide them with the possibility to bypass the university patenting system. These researchers have established positions and can sometimes afford to deviate to some extent from institutional norms and practices. The senior staff state that the university does not have a patenting culture or is only recently starting to develop that, but they gained their patenting experience in industry: "There [at the company] I encountered for the first time that everything that we did had to be documented and kept secret, with the idea that always patents had to be filed." Regarding the guidance that the researchers get at the university, they respond: "No, not at all … there was no attention to the topic." Finally, one department head identifies that some high-status scientists can go on with filing patents outside the university: "Mr. [X], he is a nice guy … and inventor of the year. He has a couple of inventions and commercialized them through a venture … that he controls himself. If you have an idea, his venture can look at it, help you with finding a company for it and they help with the patent. … But it is entirely outside academia, and thus, in fact, a threat for us, as we prefer to have it within academia on the name of the university." Confirming the differences between higher- and lower-ranked academics, an early career researcher said: "As I'm still new in the system, I need to first learn how the system works. Therefore, I am very cautious and before I do something that I am not very sure about, I would always ask whether it is appropriate." Another lower-ranked researcher remarked in a very similar way: "I am still in the process of building my human capital and social capital, therefore I want things to be done correctly and in a satisfactory way to the institute. I've never thought of bypassing the rules of the institution." Thus, as lower-ranked academics are yet learning the system and are still in the process of building their human and social capital, they are more cautious. As a result, lower-ranked academics seem more likely to abide by the institutional rules compared to their higher-ranked peers.

Finally, we test the effect of the value of the patent on the likelihood of university ownership of the patent. In Model 4 and Model 5, we tested different measures of the value of the patent and its effect on university ownership of the academic patent. More specifically, we tested the *Patent value* using the measure of triad patents, which is coded as "1" if the patent filed at all three patent offices: EPO, JPO, and USPTO. As academic patent filing was not yet a widespread practice in the university during the entire period of our study, we also used a less strict measure, *Any two of the triad patent*, which is coded as "1" if the patent is filed at any two (or all) of the above-mentioned patent offices, and "0" if otherwise. However, contradictory to what we supposed, apart from the loosely measured patent value variable *Any two of the triad patent*, the patent value does not seem to affect the university ownership of the academic patent. Therefore, Hypothesis 3 is not supported; at least in our sample, we did not find an association between patent value and the likelihood of university ownership of the patent. In the interviews, also only scarce evidence for the value effect was found. Only one interviewee mentioned that the most important patents that she invented were not filed on behalf of the university.

5.1. Robustness checks

Several robustness checks were performed to further check the validity of our results in Table 4 and Table 5. First, regarding patent value, apart from the *Triad patent* measures, following prior literature (Harhoff et al., 2003; Trajtenberg et al., 1997), we further tested the *Originality* of the patent based on its cited documents (prior art), the number of backward citations, the number of forward citations in a 5- year and 10-year time window respectively, and the number of claims the patent has made. Results are shown in Table 4, which are in line with our main

Table 4
Robustness check 1 – Patent value on university ownership of the academic patent.

Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
Originality	0.728				
	(0.938)				
Number of forward citations (5 years)		0.0143			
		(0.168)			
Number of forward citations (10 years)			−0.0280		
			(0.0719)		
Number of cited documents				0.0154	
				(0.0789)	
Number of claims					−0.00537
					(0.0169)
Number of inventors	0.124	0.105	0.124	0.114	0.121
	(0.185)	(0.188)	(0.196)	(0.189)	(0.203)
Percentage of university researchers	3.075**	3.181**	3.195**	3.185**	3.133**
	(1.413)	(1.412)	(1.394)	(1.385)	(1.387)
Gender	−2.953***	−2.899***	−2.871***	−2.909***	−2.869***
	(0.859)	(0.914)	(0.913)	(0.845)	(0.897)
Age	0.266	0.297	0.297	0.288	0.290
	(0.331)	(0.327)	(0.333)	(0.335)	(0.330)
Patent family size	−0.0152	−0.0169	−0.0249	−0.0159	−0.0197
	(0.0660)	(0.0673)	(0.0732)	(0.0657)	(0.0688)
Company applicant	−3.757***	−3.649***	−3.768***	−3.675***	−3.694***
	(0.814)	(0.862)	(0.891)	(0.854)	(0.867)
Total patents per year	−0.0431	−0.0449	−0.0375	−0.0434	−0.0411
	(0.0891)	(0.0970)	(0.0957)	(0.0914)	(0.0941)
Allocated faculty budget	0.00385	0.00442	0.00302	0.00389	0.00392
	(0.0150)	(0.0155)	(0.0163)	(0.0154)	(0.0154)
Faculty dummies	*Included*	*Included*	*Included*	*Included*	*Included*
Year dummies	*Included*	*Included*	*Included*	*Included*	*Included*
Constant	−12.22***	−12.10***	−12.13***	−12.21***	−12.10***
	(2.746)	(2.754)	(2.743)	(2.823)	(2.669)
Observations	123	123	123	123	123
Log Likelihood	−40.58	−40.87	−40.73	−40.86	−40.84
Pseudo. R-squared	0.516	0.512	0.514	0.512	0.513

Robust standard errors in parentheses.
***p < 0.01. **p < 0.05.

Table 5
Robustness check 2 – All academic inventors on the academic patent.

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Establishment of the TTO		1.797**				1.715**	1.737**
		(0.731)				(0.789)	(0.886)
Academic rank			−0.374			−0.331	−0.324
			(0.272)			(0.280)	(0.283)
Triad patent				0.128		−0.103	
				(0.490)		(0.479)	
Any two of triad patent					1.349**		1.193**
					(0.584)		(0.530)
Number of inventors	0.143	0.118	0.175	0.142	0.113	0.149	0.105
	(0.147)	(0.148)	(0.149)	(0.148)	(0.153)	(0.147)	(0.156)
Percentage university researchers	2.909***	2.645**	2.753***	2.880***	2.402**	2.560**	2.114**
	(1.065)	(1.067)	(1.021)	(1.076)	(1.067)	(1.041)	(1.052)
Gender	−1.304**	−1.345**	−1.371**	−1.302**	−1.179*	−1.408**	−1.378**
	(0.616)	(0.634)	(0.635)	(0.617)	(0.606)	(0.659)	(0.661)
Age	0.188	0.177	0.334	0.187	0.149	0.308	0.273
	(0.187)	(0.193)	(0.215)	(0.188)	(0.187)	(0.220)	(0.222)
Patent family size	0.00641	0.0252	−0.00138	0.00273	−0.0852	0.0190	−0.0335
	(0.0358)	(0.0276)	(0.0355)	(0.0392)	(0.0744)	(0.0305)	(0.0588)
Company applicant	−3.070***	−3.292***	−3.225***	−3.059***	−3.294***	−3.425***	−3.692***
	(0.551)	(0.531)	(0.637)	(0.549)	(0.593)	(0.605)	(0.668)
Total patents per year	−0.00695	−0.119	−0.0117	−0.00424	−0.0270	−0.122	−0.148
	(0.0602)	(0.0821)	(0.0617)	(0.0620)	(0.0583)	(0.0881)	(0.0943)
Allocated faculty budget	−0.00145	−0.00678	−0.00237	−0.00104	0.00159	−0.00804	−0.00606
	(0.0155)	(0.0154)	(0.0163)	(0.0157)	(0.0154)	(0.0167)	(0.0169)
Faculty dummies	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Year dummies	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*	*Included*
Constant	−13.29***	−14.67***	−13.42***	−14.61***	−13.23***	−12.64***	−12.29***
	(2.171)	(2.229)	(2.517)	(2.122)	(2.127)	(2.587)	(2.684)
Observations	188	188	188	188	188	188	188
Log Likelihood	−71.75	−69.89	−70.74	−71.73	−69.43	−69.15	−67.10
Pseudo. R-squared	0.449	0.463	0.457	0.449	0.467	0.469	0.485

Robust standard errors in parentheses.
***p < 0.01. **p < 0.05. *p < 0.1.

finding that patent value does not seem to affect the likelihood of university ownership of the academic patent.

Second, as some academic patents involve more than one university researcher, we expanded our dataset to include all academic inventors of the patent, instead of only the leading inventor (Table 5). In this set of regressions, our results suggest that the establishment of the TTO helps to increase the number of university-owned academic patents. However, when considering all academic inventors of the patent (rather than only focusing on the leading inventor), we find that the academic rank of the inventor does not seem to influence university ownership of the patent. We reflect on this and the other findings in the discussion section.

6. Discussion: contributions to extant literature

To shed light on how many university-invented patents end up as university-owned patents, and the organizational and individual arrangements influencing such patenting behavior, we performed an in-depth case study of one of the largest Dutch universities. This study uniquely combines detailed patent-inventor data covering the years 2000–2009 from this university with the analysis of in-depth interviews. Thus, we were able to shed more light on the question of what drives university's ownership of patents by considering the effect of a TTO, inventor-characteristics, and patent-characteristics at one single institution, thus limiting the effect of unobserved heterogeneity. Our results have implications for factors at the level of the university, the individual inventors, and the patent.

At the level of the university, our results show clearly that the establishment of the TTO, as part of a wider university-level change, has a significant effect on the number of university-owned patents. The overall number of academic patents increases (see Fig. 1), but the most significant change is the change in ownership: before the TTO was established on average only 13% of the academic patents were university-owned, after the establishment of the TTO this increased to 56% for the years analyzed. In our within-case study design, we avoid the effect of potential unobserved heterogeneity between cases, which might have caused insignificant effects as observed by Aldridge and Audretsch (2010) or Sterzi et al. (2019). Interestingly, we do find that even after the TTO was established, some inventors bypass the TTO, as suggested by Gianodis et al. (2016), and our qualitative evidence points out that they mainly do so for pecuniary and autonomy reasons.

Although there may be large differences between inventors and their behavior (Lam, 2010), we found in general that individual inventors who are more advanced in their career, measured through higher academic ranks, are more likely to file their patents outside the university, which is consistent with a couple of other studies (e.g., Crespi et al., 2010; Gianiodis et al., 2016). Our qualitative data gives two reasons: first, these inventors have more experience in industry and collaborations with industry, and thus are better able and more likely to sell their knowledge, sometimes even before a patent is filed. This observation also extends the findings of Meyer (2005) who found that many scientists have difficulty getting their research to the market; in turn, those with relevant commercial knowledge are more likely to commercialize their research, and thereby, sometimes may bypass the university administrative process. This is also argued by Göktepe-Hultén and Mahagaonkar (2010), who found, based on qualitative evidence that experienced inventors with existing networks in an industry sometimes do not need and want the involvement of the TTO, as they have already everything in place to commercialize an invention. The second reason, based on our qualitative evidence, for why high-ranked academics are more likely to file their patents outside the university is that they state that the university's TTO does not have enough expertise or they find it cumbersome to involve them, so they rather go for the expertise that a company can bring at the table, confirming similar findings by Meyer (2005) and Siegel et al. (2003). As such, for these experienced researchers, the role of a TTO will only make sense if it can substitute or better add to parts of the transfer process (Etzkowitz and Göktepe-Hultén, 2009). We did not find systematic evidence that these researchers were driven by expectations of personal revenue through patent commercialization to bypass the TTO, thus confirming the findings of Göktepe-Hultén and Mahagaonkar, 2010, but contrasting the findings of Gianiodis et al. (2016) who did find indications for overt opportunism in this context.

Yet, these two reasons seem to differ from those suggested by organization theories that suggest that high-status organization members can afford more freedom to operate (Colyvas and Powell 2007). At the same time, one department head gave a clear example of such a high-status individual who continued to bypass the university, thus giving support to Colyvas and Powell's (2007) explanation of the continued practice of filing patents outside the university system. Interestingly, when considering the whole academic inventor team, instead of the leading inventor, we find that the academic rank effect diminishes, while the other effects remain largely consistent. This finding may suggest that, when considering factors that influence university-ownership of academic patents, one should consider the academic status of the lead-inventor as that seems to have a significant influence on the decisions about how IP will be registered.

Finally, in our study, the value of the patent, measured in a couple of ways, is not found to be related to university-ownership of the patent, which indicates that both the university and inventors do not discriminate between patents according to their expected value. This finding contradicts most of the studies on this effect but is in line with Crespi et al. (2010). One interviewee told that the university-owned patent that she filed was the least valuable one, and the more valuable ones were filed with her own company. Yet, there is not such a pattern in the patents analyzed for this study, or the pattern is too weak to find a significant result in our sample. An explanation might be that, at least in the years before and around the founding of the TTO, both academic inventors and the TTO might not have had experience in discerning patent value and making decisions based on such a value assessment. Studies that explore the effect of TTO in later years, or involve more universities, can further explore this issue.

7. Practical implications

The issue of patenting under the name of the university has large practical relevance, as universities are propelling developments in science and economy, and are also increasingly evaluated on their societal and economic impact. Yet, often the name of the university does not appear on the patent, while the inventor is, in fact, a university researcher. Universities can only get a share of commercial revenues of inventions if they know about these inventions and can claim ownership of these inventions. Our results thus have direct implications for the governance of IP at universities, as universities may relatively easily increase their number of patents by enforcing that all university-invented patents are assigned to the university (owned or not). At a national level, such measures could be implemented in research policies as well.

Our results confirm that the establishment of a TTO is an important way to increase the number of university-owned patents. Moreover, TTO's and universities can specifically address the issue of researchers who bypass the TTO, by designing solutions targeted at the prime reasons of these—often high-ranked—researchers, such as the perceived lack of experience and capacity of the TTO. TTOs need to build up capacity and expertise to make sure that they can make a significant contribution to facilitating the commercialization processes of these academic inventors. Additionally, enforcement of technology transfer policies may be needed, for instance by checking on these activities and collaboration with the TTO in individuals' annual assessments. These solutions should primarily target high-ranked researchers, as we observed that in our case high-ranked researchers are more likely to file patents outside the university.

Assigning patents to universities also has an important legal side:

who is entitled to ownership of intellectual property? Even though that has not been the focus of this study, as we addressed the individual and university-level, our findings imply that the effect of legislation depends on the execution at university level. On the surface, the difference between university ownership of intellectual property, like in the Bayh-Dole act in the US and similar legislation all over Europe, and inventor ownership by the 'professor's privilege' in Sweden (and in the past in Germany, Finland, Norway, and Denmark), seems to be very important. Yet, studies have mixed judgments regarding the effect of these different regimes (Åstebro et al., 2019; Granstrand 2013): some argue that university ownership is more effective in making inventions available for the public (Merill and Mazza 2010), but most studies find that both systems are at least similarly effective in terms of the number of patents (Lissoni et al., 2008; von Proff et al., 2012) or that replacing the inventor-ownership with university-ownership even leads to a decrease in patenting and start-up rates (e.g., Czarnitzki et al., 2015; Ejermo and Toivanen 2018; Valentin and Jensen 2007). Short- and long-term effects of such legislation changes may be different, but in the end, the effects may be smaller than predicted as Åstebro et al. (2019) show in their comparison of Sweden and the US. Our study points at the need to understand the university- and individual-level aspects that play a role. Importantly, in the end in both systems, university managers, technology transfer offices and individual academic inventors jointly impact eventual outcomes in terms of patents and university-based start-ups (see Gilsing et al., 2010).

8. Limitations

This study suffers from some limitations. First, although we have controlled for an extensive list of potential confounding factors, as a single case study, the external validity of the study is bounded by the characteristics of this single case of a large public university in a country with Bayh-Dole-type regulation. As such, we refrain from making general causal claims in this study. Future research may be conducted in other countries and involve other universities to enhance the findings of our research and in particular to confirm the conditions and mechanisms influencing patenting behavior in- or outside the university. Moreover, in this study, we mainly focus on exploring the individual-level and patent-level factors on university ownership of academic patents. It would, however, be valuable if future studies also examine other university-level factors, besides founding a TTO.

Second, studies have shown that factors at the level of the TTO, such as budget, number of staff, and experience of the staff, have an important influence on the TTO's effectiveness (e.g., Baglieri et al., 2018; Hayter et al., 2018; Huyghe et al., 2016). While we have assessed the overall effect of the establishment of the TTO, we did not have sufficient data to model subsequent changes inside the TTO and their effect on academic patenting and thus have not been able to establish or control for the effects of these factors.

Third, we were not able to collect contracts, if any, that govern collaborations between university researchers and other parties. This limited the possibility to interpret our results in light of such collaborations. Such arrangements with industry, in particular in the form of contracts, may explain why some patents were filed under the name of a company, as they may have (partly) funded the underlying research, thus leading to fewer university-owned patents (Belderbos et al., 2014; Crespi et al., 2010). Moreover, such contracts may have provided individual incentives to give commercial rights. Further studies are needed to further assess this effect.

Fourth, although our patent data covers multiple years, our qualitative data is collected at one moment in time. As such, the interviews bear the risk of retrospective bias.

9. Conclusion

This study captures the academic patenting patterns and drivers thereof and sheds light on when inventors file patents inside or outside the university. It shows that a study of a single university is helpful to better understand the dynamics and underlying mechanisms, and as such calls for more within-case analyses to study such processes in-depth. The findings confirm that the establishment of a TTO is indeed instrumental in generating more academic patents in general and that the establishment of a TTO is particularly associated with an important change in patenting behavior as more patents based on university research are assigned to the university and relatively less to other parties. Moreover, the results show that male researchers and higher-ranked researchers are more likely to file patents outside the university, while the value of patents does not seem to affect the ownership of the patent. The quantitative results confirm emerging insights in this line of research and help to resolve inconsistencies in existing studies, while the qualitative results were in particular helpful to identify the underlying mechanisms.

Acknowledgement

This study was partly funded by the Netherlands Patent Office.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.technovation.2021.102287.

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