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Original
The licensing and selling of inventions by US universities / Caviggioli, F., De Marco, A., Montobbio, F., Ughetto, E.. - In: TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE. - ISSN 0040-1625. - ELETTRONICO. - 159:(2020). [10.1016/j.techfore.2020.120189]

Availability:
This version is available at: 11583/2839602 since: 2020-12-23T21:25:48Z

Publisher:
Elsevier

Published
DOI:10.1016/j.techfore.2020.120189

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(Article begins on next page)

16 November 2026

Technological Forecasting & Social Change 159 (2020) 120189

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

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

The licensing and selling of inventions by US universities

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ARTICLE INFO

Keywords:
Academic patenting
Patent transactions
Patent licensing
Markets for technology

ABSTRACT

Our study analyzes the patent transactions of the top 58 US universities in the yeas from 2002 to 2010. We find that 37.0% of the patents granted at the *United States Patent and Trademark Office* (USPTO) have been involved in a form of monetization. Among them, 29.7% have been licensed out, 5.9% have been reassigned to other universities, National Laboratories, federal agencies or non-profit entities, and 1.3% have been transferred to companies. We investigate the patent characteristics associated with each monetization channel (i.e., licensing and outright sale). We also introduce a set of survival model analyses to control for the dynamic nature of the monetization process. The transacted inventions in the portfolio (and, in particular, the licensed ones) are peculiar over several dimensions: they show higher value or technical merit, higher legal robustness, and higher complexity. Licensed patents differ from reassigned ones especially for a higher technological complexity. Patents transferred to companies are not frequent in the university core fields, but the corresponding market for technology is able to select those with higher value and legal robustness.

1. Introduction

The idea that patents are not simply exclusive rights granted for an invention, but are assets that can be monetized, has fostered the recent growth in the markets for technology (Arora et al., 2004; Arora and Gambardella, 2010; Cockburn et al., 2010; Monk, 2009). Competitive technology markets have a major role in increasing the global rate of innovation, improving the geographical distribution of technology (Drivas and Economidou, 2015), promoting the diffusion of technical knowledge and facilitating the matching with entities Intellectual Property Rights (IPRs) would be relevant to. An organization may transfer its patent rights through different channels (e.g., licensing agreements, transfers, mergers and acquisitions, partnerships agreements, creation of spin-offs, or outright sales). The degree of control that an entity retains on its inventions depends upon the different forms of technology transfer.

Firms and NPEs are key players on the technology markets, and in the last few decades, universities have also begun to steadily monetize their patented technologies. There has been an upsurge of university patenting since the implementation of the Bayh-Dole Act in 1980, which facilitated trading and licensing of IPRs resulting from federally funded research (seeMowery et al., 2001; Mowery and Ziedonis, 2002; Sampat, 2006; Thursby et al., 2009) .[1] The boom in the patenting activities of universities has been accompanied with an expansion of the technology monetization activities, as well as the creation of the Technology Transfer Offices (TTOs), in many academic institutions (del Campo et al., 1999; Fini et al., 2010).

The *Association of University Technology Managers* (AUTM) reported in the *US Licensing Activity Survey* (2016) that a total of 16,487 new US patent applications were filed in 2016, of which 7021 were granted to the 195 universities and research institutions that participated in the survey. In addition, the report highlighted that the dramatic increase in university patents was accompanied by a parallel increase in licensing agreements.

Monetizing academic patents may not be an easy task due to the intrinsic difficulty of academic inventions being readily marketable (Buenstorf and Geissler, 2012) and to the problems that plague the markets for technology, which can be even harsher in the case of university patents. Among the non-mutually exclusive obstacles that make the commercialization of university patents challenging we should mention the early-stage nature of inventions (Jensen and Thursby, 2001), the asymmetric information about their quality (Shane, 2002), the non-codified and tacit knowledge underlying the transacted technology (Agrawal, 2006), as well as the uncertainty about the scope, obsolescence, generalizability, and value of the patented technology (Gambardella et al., 2007; Teece, 1986).

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[1] Other explanations for this dramatic increase in academic patenting have been associated with developments in the expansion of the patentable subject matter (e.g., software, genetically modified life forms, etc.) and with the creation of the *Court of Appeals for the Federal Circuit* (Rosell and Agrawal, 2009).

https://doi.org/10.1016/j.techfore.2020.120189
Received 22 October 2019; Received in revised form 13 June 2020; Accepted 29 June 2020
Available online 10 July 2020
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Patent transactions, in the form of sales, have been studied in a limited number of empirical works, using data on patent auctions (Cahoy et al., 2016; Caviggioli and Ughetto, 2013; Fischer and Leidinger, 2014; Nair et al., 2011; Odasso et al., 2014; Sneed and Johnson, 2009) and on patent reassignments (De Marco et al., 2017; Drivas and Economidou, 2015; Figueroa and Serrano, 2013; Fusco et al., 2019; Galasso et al., 2013; Serrano, 2010, 2018). Among these, only a few works have focused on university patents (Cahoy et al., 2016; Fusco et al., 2019).

The monetization of university inventions has garnered most of the attention associated with the *Bayh-Dole Act*, with focus on changes in the quality of academic patents after the implementation of the reform (Link et al., 2011). Concerns have also been raised about the role played by universities on the markets for technology: the traditional academic focus on basic research may be distorted (Cohen et al., 1998; Henderson et al., 1998; Verspagen, 2006) with potentially detrimental effects to downstream industry research (Arora et al., 2019; Fabrizio, 2007). Despite the attention that was paid to the commercialization of university IPRs in prior works, little is known about the nature of transacted patents across the different monetization channels. The dearth of empirical evidence is not surprising, given the difficulty of gathering data on patent sales and licensing agreements as well as the paucity of information on the contractual terms that characterize these market transactions.

Notwithstanding the relevance of the topic, the commercialization of the results of scientific research, by means of the different transfer channels, has not been the subject of much scholarly scrutiny so far. This study contributes to the existing literature in three main ways. First, we offer a comprehensive understanding of the channels and features that characterize the transfer of US university patents on the markets for technology. In this regard, we complement previous literature that discussed appropriability issues and other mechanisms that facilitate the monetization of university technologies (Dechenaux et al., 2008; Elfenbein, 2007; Hellmann, 2007) by documenting the nature of the market for university patents. We investigate the nature of the transactions and identify different types of recipients (e.g., companies, research centers, and National Laboratories such as *Lawrence Livermore, Los Alamos*, and *Argonne*).

Second, we explicitly analyze the conditions under which some patents are sold or licensed out by universities with respect to the cases when no acquirer or licensee can be found. We also introduce survival model analyses to control for the dynamic nature of the monetization process. In this way, the paper offers an opportunity to understand why some university patents are taken up by the market (and in which way), while others are not. In fact, the different transaction options that are available have not been compared so far and most of the empirical studies have just focused on one transaction type (Drivas et al., 2016) or on case studies in which single or a few large universities have been analyzed (Elfenbein, 2007; Mowery and Ziedonis, 2001). To the best of our knowledge, this is the first paper that studies empirically the monetization strategies of patents implemented by the main US universities at the patent level and analyzes the specific attributes of transacted inventions.

Third, the novelty of this work relies on information retrieved from the *United States Patent and Trademark Office* (USPTO) dataset repository, including the report on *US Colleges and Universities Utility Patent Grants: Calendar Years from 1969 to 2012*, the *Patent Grant Full Text Database*, the *Patent Assignment Dataset*, the *Patent Maintenance Fee Events Database*, and the *Patent Examination Research Dataset*.

This study explores the composition of the granted patent portfolios of the top 58 US universities between 2002 and 2010. We have identified the patent transactions corresponding to sales and the presence of license agreements at the patent level using the methods described by De Marco et al. (2017) and Drivas et al. (2016), respectively. We have also compared all the types of patents in a set of econometric tests in order to explore different patent-level characteristics and to improve the understanding of patent transactions. The results show that transacted inventions (and in particular licensed ones) are different from inventions kept in the portfolio over several dimensions: they have higher value or technical merit, higher legal robustness, higher complexity, higher number of assignees and inventors. Patents reassigned to companies or NPEs are not frequent, but the corresponding market for technology is nonetheless able to select those with higher value and legal robustness.

The remainder of the paper is organized as follows. *Section 2* discusses the background literature. *Section 3* introduces the dimensions of the analyses in the context of patent monetization strategies. *Section 4* describes the data sources, the data collection process, and provides descriptive statistics. *Section 5* presents the econometric models and discusses the results. *Section 6* concludes and summarizes the paper.

2. Background literature

University research contributes to economic development and technological innovation exploiting, in many cases, *market-mediated* channels that allow universities to monetize research outputs. Universities rely on different mechanisms – ranging from licensing agreements to informal technology transfers, spin-offs and sales – to transfer and monetize scientific inventions (Colyvas et al., 2002; Jensen and Thursby, 2001; Markman et al., 2005).

The evolution in the valorization strategy of university research outputs has received an important input, from the beginning of the 1980s, with the implementation of a number of policy measures, the most important of which was the *Bayh-Dole Act*. Although US universities were active in patenting and licensing faculty inventions long before 1980, the Act facilitated these activities because it provided a uniform policy framework to retain ownership of federally funded research outcomes and any revenues resulting from their technology transfer activities (Mowery et al., 2001 and 2002). Furthermore, the Federal Government was granted the right to license federally funded inventions that had not been exploited by universities (i.e., march-in right, *University and Small Business Patent Procedures Act*), the duration and scope of patent protections were extended (Jaffe, 2000; Kortum and Lerner, 1999), and the exploitation of the research outcomes of public laboratories was progressively facilitated (Geuna and Rossi, 2011). The intuition behind these policy initiatives was that an increase in the attitude toward monetization in university research could propel industry-university technology transfer, and thus result in greater technological progress[2] (Czarnitzki et al., 2011).

The institutional and legal context significantly affects how universities manage their IP rights. In two cases a university can fully transfer the ownership of an invention (i.e., outright sale): when the invention does not derive from federal funding and when the invention is the outcome of a research supported by federal funding and the government grants permission to the transaction. In fact, the sale of a patent requires assignment to a third party. In the US, under the *Bayh-Dole Act*, universities are not allowed to assign to any third party a patent protecting an invention funded by the US Federal Government, unless they offer to return it to the Federal Government agency that funded it. If the Federal Government Agency gives its approval, universities can sell their IPRs.[3] However, it is important to emphasize that not all university patents are derived from federal funding. Inventions

[2] Some scholars are concerned about the increased monetization trends of academic research outputs, pointing out the potential threat of a substantial shift in the content of academic research from basic to applied research (Cohen et al., 1998; Henderson et al., 1998; Verspagen, 2006) and the detrimental consequences that such a shift might have on patent quality (Henderson et al., 1998) and on downstream industry innovation, as a result of a slowing down of industrial innovation (Fabrizio, 2007).

[3] For example $202 (c) (7) claims that '*In the case of a nonprofit organization, (A) a prohibition upon the assignment of rights to a subject invention in the United States without the approval of the Federal Agency, except where such assignment is made to an organization which has as one of its primary functions the management of inventions (provided that such assignee shall be subject to the same provisions as the contractor)*' […].

funded by state and local governments, philanthropic organizations, for-profit entities, or by universities themselves are not under *Bayh-Dole* obligations (Eisenberg and Cook-Deegan, 2018).

At the same time universities might have a strong preference for licensing that goes beyond the strategic issues discussed below in this paper. Licensing activities are better aligned with the *Bayh-Dole* objectives to use or develop the invention in the public interest, so that the benefits are available to the public on reasonable terms, and to protect the public from unreasonable use (National Research Council et al., 2011). Also, universities might prefer to avoid uncertain negotiations with federal agencies. Finally, the application of a uniform policy, irrespective of the source of research funding, could simplify the management of IPRs resulting from research activities with multiple funding sources and, at the same time, facilitate the management of tax exemptions and overheads on sponsored research (National Research Council et al., 2011).

According to most scholars, these policy reforms gave universities greater incentives to engage in the commercialization activities of university owned patents, thus enhancing technology transfer (Henderson et al., 1998; Sampat, 2006). Recent studies have found that the licensing of university patents induce positive signaling and informational effects in related technical fields, stimulating further research and innovation by other scientists and non-licensees (Thompson et al., 2018). Drivas et al. (2017), using data from university campuses and National Research Laboratories, empirically explore the effects of the exclusive licensing of university inventions on the rate and direction of innovation beyond academia. They find the presence of positive externalities for non-licensee innovators: forward citations by private sector non-licensees increase after exclusive licensing. Other scholars expressed some doubts that this upsurge in patenting and licensing of university inventions could be ascribed entirely to changes in university IPR regulations, as some top universities (e.g., the *University of California*, the *Stanford University*) had increased their patenting activities well before the approval of the legislation (Kenney and Patton, 2009; Mowery et al., 2001).

A significant debate, concerning the quality of transacted university patents, arose as a result of the implementation of the above-mentioned policy reforms (Eisenberg and Cook-Deegan, 2018). Concerns were raised that the increased focus of university on monetization might shift resources to lower quality patented inventions (Henderson et al., 1998; Lissoni and Montobbio, 2015; Sterzi et al., 2019). Mowery et al. (2001, 2002), Mowery and Ziedonis (2002), and Sampat et al. (2003) provided evidence that the decline in the overall quality of university patents after 1980 was associated with the catching up of new university players with limited expertise, and not to a general decline in quality of the inventions patented by all universities. However, it has been shown that the growth in the university licensing activity has stemmed from an increase in commercialization activities by the entire university system, rather than simply the entry of institutions with limited experience in the patenting arena (Thursby and Kemp, 2002; Thursby and Thursby, 2002).

The participation of universities in the monetization of IPRs faces a number of challenges on the markets for technology and the exchange of IPRs. Several problems plague the commercialization of IPRs: uncertainty about the value, scope, and obsolescence of the underlying technology (Arora et al., 2004; Gambardella et al., 2007; Teece, 1986), asymmetric information between inventors and sellers, buyers and licensees (Shane, 2002), and high search costs (Arora et al., 2004). Technology is highly idiosyncratic (i.e., it may only be of value to a few adopters) and it displays its value only when it is used, due to the tacit and non-codified nature of the knowledge base that underlies it (Agrawal, 2006; Elfenbein, 2007). These issues are intensified for commercialized academic research, because university patents cover rather basic, path-breaking inventions that are not readily marketable, and whose benefits are difficult to appropriate (Buenstorf and Geissler, 2012). An exception, in this respect, is provided by the user-inspired basic research in the Pasteur's Quadrant (Stokes, 1997). In this case the role of experienced scientists, that are active in both basic science and patenting, play an important role in monetizing IPRs and enhancing innovation in companies (e.g., biotech, advanced materials; Baba et al., 2009).

Different monetization strategies of university patents entail different levels of risks and returns, and the most appropriate one depends upon the specific characteristics of the invention. Because licensing implies royalties based on profit or revenue sharing, while selling lump sum payments, the latter is a less risky strategy (Megantz, 2002). For instance, when uncertainty is low, patent holders prefer licensing their patents rather than selling them (Jeong et al., 2013). The decision to choose between licensing out and selling might not simply depend upon the characteristics of the protected invention, but also upon the technological field and the corresponding technology transfer mechanisms (Pries and Guild, 2011; Wu et al., 2015).

The different transfer activities may be targeted to companies, NPEs, and other government-funded research organizations, each of which entails different managerial and organizational implications (Jeong et al., 2013). There has been a significant debate in the media over universities selling patents to NPEs, commonly known as *patent assertion entities* or *patent trolls* (Fusco et al., 2019). The debate stemmed from the observation that when universities sell patents to NPEs, publicly funded research is compromised (Harmot, 2016; Ledford, 2013). Even if in 2007 > 100 universities (including the *Stanford University*, the *Massachusetts Institute of Technology*, the *Harvard University*, and the *University of California*) signed a statement pledging not to sell their patents to NPEs, standing agreements to sell patents to NPEs are still in place in most academic institutions.[4] Fusco et al. (2019) find that only the 0.3% of university patents that have been transferred at least once has been acquired by NPEs. These patents are, on average, older than those transferred to producing companies and of higher quality.

A substantial body of research has examined licensing as the primary monetization tool of university inventions, discussing the characteristics, geographic distribution, and determinants of university licensing agreements with varying degrees of exclusivity (Elfenbein, 2007; Hall et al., 2003; Jensen and Thursby, 2001). Other forms of monetization of university technology have received much less attention than licensing (Kirchberger and Pohl, 2016). Cahoy et al. (2016) discuss how a proper design of auctions for selling and licensing university IPRs could maximize the benefits that universities might enjoy in IP transactions. The authors highlight that auctions are a useful tool that well aligns to the unique nature of university IPRs and provide recommendations for modifying the auction structure.

It has been outlined that the licensing strategy adopted by universities is influenced by the technological competition and appropriability regimes (Pries and Guild, 2011), the nature of the invention (Elfenbein, 2007; Jensen and Thursby, 2001; Pénin, 2010), and by institutional factors, such as contractual incentives, administrative support, or implementation of a policy reform. Concerning technology-level characteristics, for example in the case of embryonic inventions, universities tend to adopt exclusive licensing, while the dominant form is represented by non-exclusive licenses when the invention is mature and generic (Özel and Pénin, 2016). Focusing on the role of policy reforms, Drivas et al. (2018) examine patented inventions licensed at the *University of California* and estimate the dynamic effect of the publication of patent applications and grants on the conditional hazard of

[4] Ewing and Feldman (2012) show that 45 universities around the world licensed or sold patents to *Intellectual Ventures* shell companies, while Katz (2016) report that nearly 500 patents currently owned by *Intellectual Ventures* originally belonged to universities, including state schools. However, patents reassigned to NPEs are not frequent in our sample (3%). An in-depth analysis of the phenomenon can be found in Fusco et al. (2019).

Table 1
relationship between the characteristics of patented technologies that affect the likelihood of a patent being transacted and patent bibliometric indicators.
Sources and references: Allison et al., 2003; Bacchiocchi and Montobbio, 2009; Caviggioli and Ughetto, 2013, F. 2016; Gans et al., 2008; Hall et al., 2005; Harhoff et al., 1999, 2003; Harhoff and Wagner, 2009; Harhoff and Reitzig, 2004; Jaffe and De Rassenfosse, 2017; Kuhn et al., 2020; Lanjouw et al., 1998; Lanjouw and Schankerman, 2001, 2004; Lerner, 1994; Meyer, 2000; Merges and Nelson, 1990; Palomeras, 2007; Régibeau and Rockett, 2010; Reitzig, 2003; Schmoch, 1993; van Zeebroeck and van Pottelsberghe, 2011; Wagner and Wakeman, 2016.

Patent bibliometric indicator	Characteristics of the patented technology			
	Value and technical importance	**Legal robustness**	**Technological complexity**	**Science basicness**
Number of assignees	☑		☑	
Number of inventors	☑		☑	
Number of claims		☑	☑	
Number of words in the first independent claim	☑	☑		
Technological scope			☑	
Backward citations to patents		☑		
Backward citations to non-patent literature				☑
Time-to-grant			☑	
Geographical scope	☑	☑		
Forward citations to patents	☑			

licensing, distinguishing the periods between, before, and after 1999, year of the implementation of the *American Inventors Protection Act* (AIPA). They find that after AIPA patent grant does no longer play a significant effect on licensing hazard. Rather, it is the publication of a patent application at the eighteenth month after filing that significantly increases the licensing hazard.

Academic licensing (and especially exclusive licensing) is affected by geographical distance (Mowery and Ziedonis, 2001) and there is a tendency to concentrate near the university. Federally funded university patents have been found to be equally likely to be licensed as non-federally funded ones, although they are less likely to be licensed early compared to their non-federally sponsored counterparts (Drivas et al., 2016).

Other studies have focused on the individual perspective to assess how the individual characteristics of researchers (e.g., perceptions, background, and experiences) affect university-level variation in research commercialization (for a discussion, see Wu et al., 2015; Baba et al., 2009).

3. Invention characteristics and patent monetization strategies

Studying the monetization strategies of university patents is a challenging task because the dynamics at work can be complex and multifaceted, and can be explained by a mix of institutional, economic, and technological factors that are dependent to a great extent upon the specific context of investigation. So in this paper we follow an exploratory approach and our goal is to analyze the channels and features that characterize the transfer of US university patents on the market for technology, rather than developing and testing a specific theory (e.g., Fischer and Henkel, 2012; Harhoff et al., 2003; Harhoff and Reitzig, 2004; Wagner and Wakeman, 2016). In this section, we discuss which features at the patent level are associated with the likelihood of university patents being transacted. We also investigate to what extent the specific attributes of these inventions drive the two different monetization channels, namely licensing and outright sales.

3.1. The tradability of an invention

Our starting point is that the likelihood of observing a transacted patent depends on the tradability of the invention itself. The latter outcome is affected to a great extent by two forms of uncertainty: the technological uncertainty related to the opportunities of product and market development of the invention, and the legal uncertainty related to the possibility of effectively protecting it (Gans et al., 2008; Wagner and Wakeman 2016). The technological uncertainty of a patent influences the university patent monetization potential. It is directly related to the complexity of the invention and inversely related to its potential redeployability, which, in turn, has an impact on the probability of observing a transaction (Tietze, 2012).

The focus on university patenting requires some additional considerations. Universities are expected to pursue goals that are different from those of companies. The main goal of a university is to achieve a quick and broad dissemination of its generated technology for the good of society. This implies that strategic patenting is very limited, and universities have limited incentives to keep idle patents in their portfolios (Merrill and Mazza, 2011). Moreover, academic patent applications reflect in many cases more basic research, and the transfer of knowledge into practice may occur through a variety of mechanisms.

Bearing in mind the specificities of the university environment, we have identified four invention characteristics that affect the likelihood of a university patent being transacted: patent importance (or technical merit), legal robustness, complexity, and science basicness. We expect these dimensions to drive the easiness of licensing or selling an invention, to affect the level of uncertainty of the monetization process and the possibility of bringing profitable products to market. In particular, an increase in patent importance and legal robustness reduces the uncertainty surrounding a patent, while an increase in the level of complexity and basicness of inventions is potentially associated with a higher level of uncertainty.

Bibliometric information on patents can be used to measure such four characteristics of inventions (Bessen, 2008; Hall et al., 2005; Harhoff et al., 1999 and 2003) and, in turn, the tradability of the invention, as shown in *Table 1*. The same bibliometric measure could be correlated with different features of the invention, according to the reviewed interpretations of the variables derived from patent indicators (Jaffe and de Rassenfosse, 2017; Trippe, 2015; van Zeebroeck and van Pottelsberghe, 2011). For example, the number of claims of a patent is correlated with both its legal robustness and complexity. However, complexity and legal robustness may have opposite effects on the probability of a patent being transacted.

3.1.1. Value and technical importance

Patent value and technical importance reflect the technological value of the underlying innovation and are approximated in most of the scientific works with forward patent citations (Bacchiocchi and Montobbio, 2009; Hall et al., 2005; Harhoff et al., 1999 and 2003; Harhoff and Reitzig, 2004; Jaffe and De Rassenfosse, 2017; Lanjouw and Schankerman, 2004; Reitzig, 2003; van Zeebroeck and van Pottelsberghe, 2011). Universities do not have incentives to keep the most promising and valuable technologies for internal development, nor do they have the capabilities of bringing them to the market. So it is likely that patented technologies become available for licensing

or sale on the markets for technology (Elfenbein, 2007). If a patent is important and valuable, companies will be interested and willing to purchase it. Universities might therefore demonstrate a higher propensity to license out or sell a patented technology with great potential because of the higher chances of finding a potential buyer or licensee.

The geographical scope of a patent represents an additional measure of value that indicates how large the expected market for the patented technology is. It is generally calculated as the number of jurisdictions in which patent protection is sought. On the one hand, if universities consider an invention valuable, they seek to designate the patent for a large number of countries (Lanjouw et al., 1998). In doing so, they are also prepared to face a considerable increase in total patenting expenses and potential oppositions (Harhoff and Reitzig, 2004). On the other hand, the greater the geographical coverage of the protection is, the lower the legal uncertainty surrounding the technology and the greater the possibilities of commercializing the patent.

The number of inventors and assignees can also be considered as a measure of the importance of a patent. In fact, large and important projects are often the result of a broad collaboration between different teams and institutions.

3.1.2. Legal robustness

The legal robustness of a granted patent can be measured by the count of backward patent citations. If these citations have already been evaluated as non-blocking, they may reflect a decreased level of uncertainty (F. Caviggioli and Ughetto, 2016; Lanjouw and Schankerman, 2004). It is important to note that the interpretation of the number of backward citations as a proxy of legal robustness might have a less clear understanding when it comes to the likelihood of litigation and when considering patents issued in the last decade. Scholars found opposite results in terms of correlation between backward citations and litigation (positive in Lanjouw and Schankerman, 2001; negative in Allison et al., 2003). The recent work of Kuhn et al. (2020) highlighted the presence of inconsistencies in the use of backward citations as a time consistent proxy, due to changes in the average number of references provided by applicants. For this reason, we have tested our empirical models also excluding the number of backward citations.[5]

The number of patent claims provides an indication of the legal scope and robustness of the protected innovation, and it is therefore correlated with its value (Lanjouw and Schankerman, 2004) .[6] A broader-in-scope patent is generally considered to be more legally sound, because it lowers the chance of competitors *inventing around* the patent (F. Caviggioli and Ughetto, 2016), thus reducing uncertainty and the possibility of legal infringements. However, the literature has also pointed out that a higher number of claims may simply reflect the drafting style of the patent attorneys[7] (van Zeebroeck and van Pottelsberghe, 2011).

The geographical scope of the patent, which reflects the family size, also provides an indication of the legal robustness of the patent.

The recent work of Kuhn and Thompson (2019) has suggested that the number of words in the first independent claim of a patent can be considered as a proxy of the patent scope: the longer the text, the more specific and narrow the scope of the invention.

3.1.3. Technological complexity

Complex patents might be less easy to embed in commercial products, because their development is more uncertain, and the commercialization process may imply higher transaction costs. More complex patent rights could generate divergent expectations on their monetization opportunities and enhance information asymmetries between the parties involved.

At the same time, the acquirer or licensee could take advantage of a complex technological innovation developed by a university, instead of investing its own resources and time, with a high risk of failure, to obtain the same result. A complex patent could fill the need of a potential third party to develop a technology that requires a specific knowledge base which is lacking at a firm level. Hence, a complex patent could also be more valuable, because the chances of the patent being transacted are higher.

Disentangling complexity from importance is not an easy task, as some indicators correlate with both of the characteristics of innovation. For example, the technological scope of a patent, as well as the number of assignees and inventors are characteristics that indicate that a patent can be both of high technological merit and of high complexity.

The technological scope of a patent is usually approximated with the number of IPC codes (e.g., Harhoff et al., 2003) and refers to the possible fields of application of the technology. The broader the scope, the greater the number of products or processes that can be derived from the technology (Harhoff et al., 2003; Lerner, 1994; Merges and Nelson, 1990; Palomeras, 2007). Accordingly, a patent with a broader scope may have a greater potential of being transacted, since it will attract more licensees or acquirers and will provide the seller with a broader range of opportunities to exploit the underlying technology. On the other hand, Harhoff et al. (2003) show that the technological scope is not correlated with the patent value, and the possible reason for this is that complex patents, as emphasized above, might not be easily transferred into commercial products.

The number of inventors and assignees is used to identify complex projects and may also affect transaction costs. However, a higher number of dedicated inventors might also be the result of a collaboration of teams from multiple research laboratories from universities or companies and might also be at the origin of valuable patents.

Finally, the time-to-grant can be considered as a proxy of complexity and of higher technological uncertainty (Harhoff and Wagner, 2009; Harhoff and Reitzig, 2004; Régibeau and Rockett, 2010). The duration of the examination process is affected, among others, by the inherent complexity of the subject matter. Such complexity could generate difficulties in the interaction between patent applicants and patent examiners. The uncertainties that hinder the monetization process could play an even more important role when grant lags are longer (Gans et al., 2008; Wagner and Wakeman, 2016).

3.1.4. Science basicness

University inventions are expected to have a very close link with science. Basicness of research is captured by the number of backward citations to scientific articles (Meyer, 2000; Schmoch, 1993), which offers information on how close the protected invention is to basic science. Basicness of research has been indicated as an obstacle to commercialization for corporate patents (Caviggioli and Ughetto, 2013). While patents covering a basic technology have a low immediate monetization value, others that protect more incremental (less basic) technologies may easily find a technological application to build upon.

[5] Kuhn et al. (2020) suggested that measures based on the count of backward citations are likely to include long-term residual trends and more accurated results could be obtained by properly considering time, sector and cited-citing metrics as weights. Due to the small economic significance of this variable in our models, our analyses are limited to the test of the regression results without the count of backward citations. Further research can improve our findings by introducing a refined version of the count of backward citations.

[6] Since the USPTO applies a fee scheme where each claim in excess of 20 has an additional cost, the number of claims could proxy the economic involvement in the invention. We argue that the extra-fee is of limited relevance when compared to the whole patenting cost which includes the attorney fee and, in case of international relevance, the cost of extensions. However, the variable has been considered in the empirical analysis as an additional control.

[7] In our sample we find a local mode in the distribution of claims at 20, similarly to the results in Archontopoulos et al. (2007). As a robustness, we have built an alternative variable that distinguishes between patents with less than 21 claims and keeps the original number of claims for patent with more than 20 claims. Such a measure could be considered the ex-ante investment in the invention.

The impact of the basicness of research on the monetization of university patented technologies reflects the dynamics of the markets for technology in which university patents are traded. If the markets for technology of university patents are similar to corporate ones, it follows that patents that are closer to basic science will be less likely to be transacted and the corresponding protected technologies commercialized. On the contrary, patents that are closer to basic science could have higher chances of being transacted if the acquirers find it particularly valuable to buy or license-in general patents from universities with close links to the scientific discoveries embedded in scientific publications. Also, patents in the Pasteur's Quadrant (Stokes, 1997) could have higher chances of being transacted. In this case patents derive from basic research but at the same time are also very close to a potential economic exploitation.

3.2. Monetization strategies: licensing versus selling

Universities can monetize their patented inventions through two main channels: licensing and selling. The licensing strategy is characterized by diverse payment schemes that can differ greatly and depend on the characteristics of the invention and of the parties involved in the agreement. The licensing contract can include a fixed-fee contribution, royalties based on revenue sharing, or combinations of the two approaches, with more complex plans involving a switch from fix to variable payments in case of commercial success for the licensed technology and reaching a determined threshold value. Selling typically implies a lump-sum payment.

AUTM (2016) showed that licensing is the preferred monetization strategy for university patents. This approach allows the uncertainty of commercializing novel technologies to be overcome in two ways: by splitting the risk between the seller and the acquirer and by delaying the payment of the royalties to the future and associating them to the commercial revenues of the product that embeds the invention. Licensing also ensures a higher degree of freedom in the bargaining process, long-term cash-flows and, in the case of non-exclusive licenses, the option of identifying multiple licensees and of retaining control over the invention with the possibility of imposing use restrictions. However, if the degree of technological uncertainty is particularly high, the incentive to sell a patent may be higher than that of licensing the patented technology (Jeong et al., 2013).

Licensing agreements may be regarded as a preferred option to outright sale. A licensed technology can generate higher cash flows in the long run, while accounting for commercialization uncertainty: the licensee is able to delay the royalty payments and to link them to the success of the innovation. Even when a patent is granted, it embeds legal uncertainty, due to the scope of the freedom to operate and potential future litigations. Licensing could also be a preferred option when multiple assignees and inventors are involved, thus implying higher transaction costs in selling the patent and fully yielding the ownership. On the contrary, a university might not be able to reach any potential interested counterparts, as in those cases when the technological sector is not one of those in which the university is particularly active: as soon as a potential acquirer is interested, it might be easier for a university to sell the technology instead of trying to define a royalty scheme in an unknown field.

4. Dataset

4.1. Data collection

The novel and original dataset used in this work results from the combination of multiple data sources and includes information on the patent portfolio of US universities and their bibliometric characteristics, as well as information on whether patents have been subject to market transactions or licensed out by universities to third parties.

In order to build the dataset, we first selected the most active academic institutions in terms of patenting activity from the report *US Colleges and Universities Utility Patent Grants: Calendar Years from 1969 to 2012*.[8] The sample includes 58 universities, whose patents represent 75% of all the patents issued to all US universities and colleges in the considered years (USPTO, 2012). Second, we collected raw data on the patent portfolios for each university from various sets of files in the *Bulk Data Storage System* (BDSS) repository of the USPTO (i.e., the *Patent Grant Full Text Database*). We retrieved an extensive set of characteristics for each patent: the relevant dates, the priority country, the assignees and inventor names as well as other patent bibliometrics (e.g., the number of claims, IPC classes, backward and forward citations, etc.) and the *INPADOC* family identifier.[9] The patents were then matched to the corresponding *Standard Industrial Classification* (SIC) field, following the *MERIT Concordance Table* in Verspagen et al. (1994). Third, we derived the names and any changes to the list of assignees from the *Patent Assignment Dataset*. We acquired comprehensive information on patent renewals via the *Patent Maintenance Fee Events Database* and the *Patent Examination Research Dataset*. All the patents granted by the USPTO are subject to the payment of maintenance fees at pre-determined intervals, that is four, eight, and twelve years after issuance, in order to remain in force.[10] In particular, the dataset reports the maintenance fee event codes and dates, as well as the size of the entity that pays the fee.

We collected the portfolio of patents owned at the grant date for each academic institution in the sample, by searching for university names in the list of patent assignees at the USPTO. Our procedure accounts for variations or non-exact name matches, as well as for the use of Technology Transfer Office (TTO) and university acronyms.[11] Moreover, patents attributed to different campuses of the same academic institution were merged into single entities.

With the aim of identifying patents that have undergone a change of ownership, we implemented the approach originally developed by Serrano (2010) and later modified by De Marco et al. (2017). The algorithm is based on the fuzzy comparison and on the matching of the assignee, assignor, and inventor names found both in patent assignment records and in issued patents at the grant date. The method identifies false positive assignments (e.g., from the inventors to their employer) and administrative events (e.g., changes of assignee names) that are not actual changes of ownership.[12] The resulting database records the

[8] The report includes all the US academic institutions that have been granted at least one utility patent (available at https://uspto.gov/web/offices/ac/ido/oeip/taf/univ/univ_toc.htm, last accessed in October 2018).

[9] We relied on the INPADOC identifiers to reconstruct patent families. An extended patent family is a set of patents that are linked to each other through priority claims and protect the same (or similar) technical matter. Family members have at least one priority in common, either directly or indirectly.

[10] The standard maintenance fee schedule for large entities provides for the payment of 1,600 USD, 3,600 USD, and 7,400 USD that are due, respectively, at 3.5, 7.5, and 11.5 years after issuance. Such amounts are reduced by half if the patent applicant qualifies as a small entity.

[11] The information on TTO names has been manually derived from the official websites of the selected universities. A non-exhaustive list of examples includes *The UAB Research Foundation; Research Foundation of the University of Central Florida Incorporated; University of Florida Research Foundation, Incorporated; Florida Research Foundation, Incorporated; University of Maryland Baltimore, Office of Commercial Ventures and Intellectual Property*; STC.UNM; *Science & Technology @UNM; Science & Technology Corporation @ University of New Mexico; Science & Technology Corporation at UNM; Purdue Research Foundation; University of Utah Research Foundation; Utah Research Foundation, University of Utah; Washington Research Foundation*.

[12] We also removed the records in which the buyer and the seller were the same organization. A limitation of the data source is that the recordation of patent transactions at the USPTO is not compulsory and might lead to potentially biased figures because of underreporting. Nevertheless, patent attorneys recommend the disclosure of changes in patent ownership since patent holders are legally protected against subsequent assignments or previous interests only

traded patents and the names of the involved parties, the new assignees (i.e., the buyers) and the assignors (i.e., the sellers). When a patent is included in multiple subsequent assignments, we consider only the earliest transaction by execution date. As a further refinement, we enriched the collected data by directly reading and analyzing all the new assignees in order to distinguish among individuals, firms, universities, research centers, TTOs, hospitals and healthcare providers, non-profit entities, National Laboratories and Federal Agencies, and NPEs.[13]

We identified the licensing activity of the selected universities following the procedure of Drivas et al. (2016). The authors used the patent maintenance fee scheme that applies to the US patent system as a way of identifying licensed patents: in small US firms, academic and non-profit organizations are eligible to pay the *Small Entity Status* (SES) renewal fees for their patents. When a large company enters into a licensing agreement with a university to develop and market its technology, the academic institution is required to pay all the subsequent maintenance fees with reference to the *Large Entity Status* (LES) scheme. We detected such changes in the entity status in order to infer that, for a specific patent, a license was granted by the university to a third party. Hence, the method makes it possible to capture the licensing events to large companies and all those to startups and SMEs that either grow enough to fall under the LES fee or are acquired by a large company before the end of the patent life. The main limitation of the approach is that it fails to identify an event of licensing out exclusively to small firms and, in particular, university start-ups, that are neither acquired nor grow enough in the years after the patent grant. Accurate patent-level data that provide indicative evidence of the relative presence of this type of licensing agreements are not readily available. We tried to collect information on the share of university patents licensed exclusively to small entities, from the previous literature and directly from university TTOs. Rough estimates calculated on single cases show that the identification error due to licensing agreements with small entities, although being a clear limitation in our analyses that should be tackled in the future, should not prevent us from performing our tests.[14]

In the final dataset, each granted patent is categorized according to the identified transaction event: licensed out, reassigned to companies, reassigned as an administrative reconfiguration to non-profit entities, or in the *residual group*. The latter category includes all the patents transferred from the university to its TTO as well as those assigned to the university which have not been transacted yet; as explained in the above paragraphs on the limitations of the methodology developed by Drivas et al. (2016), this group might also include those granted patents exclusively licensed to small entities (e.g., startups), whose relative relevance is not possible to ascertain from the current set of available information.

It is important to note that our methodology makes it possible to identify patents that are transacted to other universities, national laboratories, federal agencies, non-profit organizations, research centers, and hospitals.[15] These transactions occur in bundles of patents, suggesting that the involved patents are reassigned as a consequence of a co-development of the invention and a subsequent administrative reconfiguration of the ownership. Hence, this type of patent transaction cannot be considered as outright IPRs sales and has thus been included in a separate category (i.e., *reassigned as administrative transaction*).

4.2. Descriptive statistics

Our final database consists of 24,815 patents assigned to 58 universities between 2002 and 2010. The average patent portfolio size is 427.8 units. *Table 2* shows the distribution across the industrial sectors identified by the SIC fields. The main sectoral field is *Pharmacy*, which accounts for 39.2% of the university patents, and it is followed by *Instruments* (34.2%), and *Chemistry* (29.2%).

Table 3 reports the distribution of the patents in the portfolio of US universities by transaction type: less than two thirds (63.0%) of the patents have never been involved in any form of transaction according to our method (*residual group*); 29.7% have been licensed out[16]; 5.9% of the sample has been reassigned to other universities, national laboratories, federal agencies, or other non-profit entities *(reassigned as administrative transactions)*; 1.3% of the patents have been reassigned to a company. On average, each of the 58 universities licensed out 127.3 patents and reassigned 5.7 patents to companies or NPEs.

The collected sample also contains 1985 abandoned patents (8.0%): these are granted patents for which we did not find any paid renewal fee at the date we collected the information from the USPTO register. These patents, in line with the traditional literature on patent value (Harhoff et al., 1999; Lanjouw et al., 1998), differ from maintained ones because of a lower technical merit (40% fewer forward citations) and a longer time to grant (i.e., eight months). We were unable to assess whether the abandoned inventions had been licensed out before the first payment deadline, that is, at year four. However, we argue that a patent for which the university has expectations of technological and economic relevance (i.e., which is worth being licensed out) is very unlikely to be abandoned in the first four years (i.e., before the first maintenance payment deadline). Hence, we expect that the identification error of false negative, that is, licensed patents that are abandoned before year four after granting, will be negligible.

The analysis of the evolution of the composition of aggregate patent portfolios of US universities is shown in Fig. 1.[17] The share of licensed patents appears to be increasing and reached 23.7% of the total portfolio in 2010. However, the first and the last years might be underestimated, due to the truncation effect of the data selection. The

(*footnote continued*)
if they have effectively recorded the transfer of patents at the USPTO (Dykeman and Kopko, 2004; Serrano, 2010).

[13] Entities are identified as NPEs according to results of online searches on platforms like *PlainSite* (http://plainsite.org) or *RPX* (http://insight.rpxcorp.com) and from previous literature (e.g., Caviggioli and Ughetto, 2016; Feldman and Ewing, 2012; Hagiu and Yoffie, 2013; Wang, 2010). In our sample, the identified NPEs are Innovation Management Sciences, LLC; Intellectual Ventures Holding, LLC; IP Reservoir, LLC; Lot 25D Acquisition Foundation, LLC; Mosaid Technologies, Inc; Open Invention Network, LLC; Prosta Torra NV, LLC; Research Corporation Technologies, Inc; Resource Consortium, Ltd.

[14] We have been able to identify only in the work of Dechenaux et al. (2008) a sufficient level of disclosed details to provide a tentative comparison with our method. The authors analyzed a sample of 805 exclusive licenses managed by the *MIT Technology Licensing Office* from 1980 to 1996. Their unit of analysis is the license agreement and one third of the patents in their sample consisted of exclusive licenses to start-ups. Neither the size of the total patent portfolio, nor the number of patents in each license agreement, or the amount of other non-exclusive cases are reported. Combining data from the *USPTO Patent Technology Monitoring Team* (http://developer.uspto.gov/visualization/university-patent-count-expenditures, last accessed in July 2019), we are able to roughly estimate the share of licensed patents for the MIT (where licensee can be of any size) at 60%. Data for MIT in our sample (from 2002 to 2010) show a similar share of licensed patents (56%).

[15] Patents reassigned to the TTO of the same university are considered as non-traded, whereas those reassigned to other universities might be related to the staff relocation of researchers and involve compensation mechanisms between the two universities. However, due to the nature of the involved actors and the motivation, we have considered these types of transaction to be more similar to those of the administrative type than to a direct sale of IPRs.

[16] Our finding is in line with the aggregate values, in terms of number of licenses, reported in Van Norman and Eisenkot (2017).

[17] The joint representation of the different statuses is not immediate, and the reported Figure 1 attempts to offer a yearly snapshot of the portfolio composition. In fact, the *residual group* and the *licensed out* patents remain so until renewal fees have been paid, while reassigned patents are no longer in the patent portfolio of a university once they have been traded. Furthermore, licensed patents can only be identified with respect to the renewal dates, that is, 4, 8, and 12 years after grant, leading to an underestimation of the earliest years in the examined sample (not shown).

Table 2
top 10 SIC fields by number of patents in the examined sample of patent portfolios of US universities.

Standard Industrial Classification (SIC)	Number of patents in the sample	Share of the total patents
Pharmacy	9728	39.2%
Instruments	8485	34.2%
Chemistry, except pharmacy	7239	29.2%
Food, beverages, and tobacco	4043	16.3%
Electronics	2648	10.7%
Other machinery	2258	9.1%
Electric machinery, except electronics	1732	7.0%
Computers and office machines	1568	6.3%
Metal products, except machines	852	3.4%
Other industrial products	781	3.1%
Others	280	1.1%

Note: one patent can belong to more than one field, our elaboration is derived from the application of the *Merit Concordance Table* (Verspagen et al., 1994).

Table 3
distribution of the patents in the portfolio of US universities by transaction type.

Type of transaction	Number of patents (in the average portfolio of a university)	Share of the total patents
Residual group (not licensed to large entities nor reassigned)	15,635 (269.6)	63.0%
Licensed out	7382 (127.3)	29.7%
Reassigned as administrative transaction	1465 (25.3)	5.9%
Reassigned to companies or NPEs	333 (5.7)	1.3%
Total	24,815 (427.8)	100.0%

Note: the *residual group* might include patents exclusively licensed to small entities and never acquired by larger companies.

transacted patents, either licensed or reassigned to companies and NPEs, show, on aggregate, a steeper increasing trend than those which have not (yet) been economically exploited.

Almost all of the licensed out patents (91.6%) registered a change in the type of fees at the first payment step, that is, at year four. Later licensing-out events are rarer, as shown in *Table 4*. The result is in line with previous literature that noted that many academic inventions are licensed near the time of invention disclosure as result of a pre-arranged agreement with research sponsors or collaborators (Elfenbein, 2007; Drivas et al., 2018). Universities have incentives to settle the agreement before the patenting process is concluded and have the related costs covered by the licensee.

Table 4
timing of the licensing-out according to the payment of the renewal fees.

Time of licensing out (switch to the LES scheme)	Number of patents (in the average portfolio of a university)	Share of the total licensed patents
Before year 4	6762 (116.6)	91.6%
After year 4 and before year 8	528 (9.1)	7.2%
After year 8 and before year 12	92 (1.6)	1.2%

The analysis on patent reassignments is shown in *Table 5*. The identification method distinguishes between patents reassigned to companies (15.2% of the total reassignments), NPEs (3.0%), and individuals (0.3%) on the one hand as well as research and non-profit organizations on the other. The first group includes those transactions that are more likely to be the result of outright sales of IPRs. The second group includes those transactions that are more likely to occur as a consequence of an administrative change of ownership than sales with monetary compensation. They involve the following recipients: National Laboratories (66.1% of the total reassignments), Federal Agencies (7.7%), hospitals, health systems or non-profit organizations (6.9%), and other universities (5.5%).

We investigated the frequency of reassignment between the assignors (i.e., the universities) and the new assignees to improve the understanding of the transactions. The most frequent pairs include the *University of California* as the assignor and three national laboratories, namely *Lawrence Livermore* (579 reassigned patents), *Los Alamos* (389), and *Argonne* (220) as recipients. These three new assignees cover all the reassignments to National Laboratories and represent two-thirds of the identified reassigned university patents.

Focusing on the type of reassignments that involve companies, NPEs, and individuals (i.e. the potential sales of IPRs), we find that 39 universities (67.2% of the sample) transferred at least one patent. For this set of universities, the average number of patents reassigned to companies or NPEs is 8.5. The *University of California* is the largest seller with 54 patents, followed by the *University of Texas* with 53 patents. Six universities (15.4% of those involved in at least one reassignment) traded their patents with a single counterpart, 27 universities (69.2%) with more than one and less than five new assignees, and 6 universities (15.4%) with more than five entities.

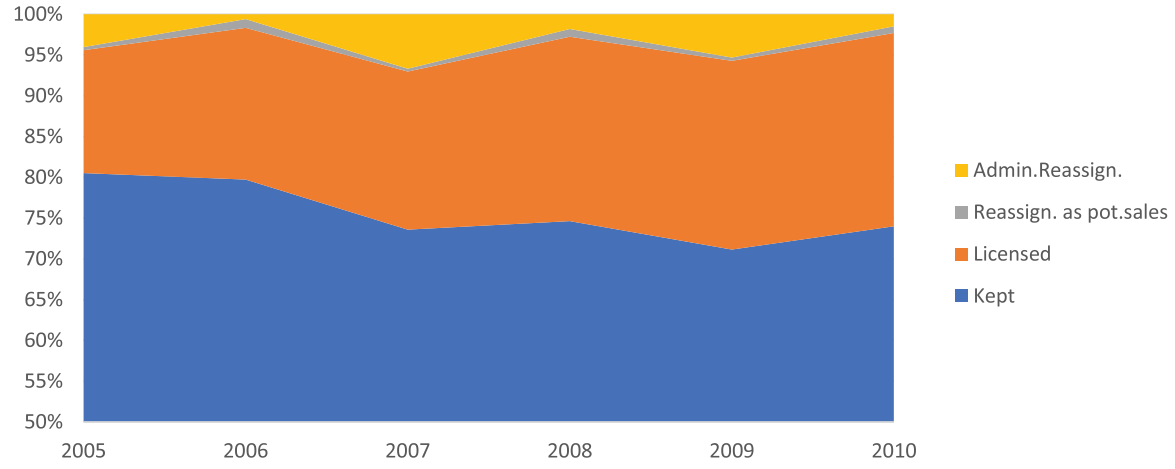


Fig. 1. evolution of the composition of the selected US university patent portfolios broken down according to the type of ownership and transaction
Note: Licensed patents are counted with reference to the years zero, four, or eight after grant, according to the subsequent date of the renewal fee.

Table 5
distribution of the patents in the portfolio of US universities by reassignment type.

Type of transaction	Type of new assignee	Number ofpatents	Share of the totalreassigned patents
Reassigned as potential sale	Companies	273	15.2%
	NPEs	54	3.0%
	Individuals	6	0.3%
	Total	**333**	**18.5%**
Reassigned as administrative transactions	National Laboratories (*Livermore, Los Alamos*, and *Argonne*)	1188	66.1%
	Federal Agencies (e.g. *National Institutes of Health, Department of Defense*, etc.)	139	7.7%
	Hospitals, health systems, and non-profit entities	124	6.9%
	Universities	99	5.5%
	Total	1465	81.5%

Note: some administrative transactions involve more than one recipient.

From the perspective of the technology acquirers, we identified 131 entities, with an average number of traded patents equal to 2.54, ranging from one (80 cases or 61% of new assignees) to 42. The largest recipient assignees are *EUV* (42 patents) and *Intellectual Ventures* (32) .[18] The traded patents derive from a single university in 95.4% of cases.

With the aim to shed further light on the collaboration patterns between the examined universities and other R&D partners, we collected additional data on patent co-assignments.[19] We find that 15.3% of all granted patents in our sample are the result of collaborative research (13.7% of patents have one co-assignee, 1.5% have two, and only 0.2% have three or more). Among the co-assigned patents, we identified 53.5% cases when the co-owner is a company, 38.9% is a partner university, 6.0% is a governmental organization, 4.7% a hospital or a research institution, and 0.5% an individual inventor.[20] *Samsung Electronics* is the entity with the highest number of co-assignments (58 patents), followed by *General Electric* (32), *Centocor* (32), *Universal Display Corporation* (26), *Human Genome Sciences* (26), and *Boeing* (24).

4.3. Focus on the sub-sample of patents with a second renewal

Patents that have been renewed twice (i.e., renewal fees are paid in both years 4 and 8) represent the group of inventions that the university considers of greatest relevance. At the same time, paying the fees without a commercial partner is a risky strategy., So the analysis performed on patents not yet transacted at the second renewal rate is particularly interesting. *Table 6* reports the distribution of granted patents that have been renewed twice across the different transaction types. The share of patents in the *residual group* is smaller than the whole sample (54.3%). However, as mentioned above, these patents, while likely reflecting high-quality inventions (because of the second renewal), may be potentially very risky for universities, because they have not found a licensee or a buyer yet.[21] Concerning the reassignment channel, the sample of patents with a second renewal shows a higher incidence of potential sales to companies.

Table 7 illustrates the distribution of the time of licensing out for the sub-sample of patents renewed twice: the largest incidence of patents consists of previously licensed inventions (84%). The residual percentage (15.6%) is made of patents that have been licensed out after the second (or the third) renewal date. This group includes those high-quality inventions that required further time before being transacted.

Table 6
distribution of the patents in the portfolio of US universities by transaction type for the sub-sample of patents with at least two renewals.

Transaction type	Number of patents	Share of the total patents
Residual group (patents not licensed to large entities and not reassigned)	5647	54.3%
Licensed out	3962	38.1%
Reassigned as administrative transaction	604	5.8%
Reassigned to companies or NPEs	195	1.9%
Total	10,408	100%

Note: the *residual group* might include patents exclusively licensed to small entities which have also never been acquired by larger companies.

5. Empirical analysis

In this section, we have modeled the mean probability of monetization for university patents as a function of observable patent-level characteristics. It is important to underline that we do not claim causality in this empirical exercise. In fact, as explained in *Section 3*, we are interested in discussing how indicators that approximate a set of invention characteristics for each patent are associated with the outcome in terms of patent monetization. We are well aware that the prospective value of a patent could change the application strategy of the TTOs and, in turn, this could affect the bibliometric indicators at the patent level. Administrators will put more effort into the economic exploitation of valuable inventions, which might also improve the way they seek stronger patent protection (Sternitzke, 2010). This could be a source of endogeneity related to both the geographical scope and the number of claims of the patents. Assignees, for example, will only apply for larger international patent protection if the expected private value of an invention is high. These measures could also be endogenous to private information the applicant has about the underlying product. In addition, we do not exclude that when the chances of monetizing patents resulting from scientific research are higher, university administrators are more careful about citing prior art and scientific background or about better drafting a patent application, thus enhancing the chances that the patent will be granted and in a shorter time (Drivas et al., 2016).

Furthermore, recent works introduced the hypothesis of a signaling effect of citations when considering licensing activities (Drivas et al., 2017; Thompson et al., 2018), suggesting a potential endogenous relation between the number of forward citations and the likelihood of licensing. However, the work of Drivas et al. (2017) does not provide significant evidence supporting this *growing demand* hypothesis.

Our study explores the characteristics of the transacted patents of

[18] If the two *Intellectual Venture* shell companies, i.e. *Lot 25D Acquisition Foundation LLC* and *Prosta Torra NV LLC*, are considered jointly with the holding, the total number of acquisitions is 38.

[19] Since assignment information is dynamic and patent ownership can change over time, we opted to focus on the grant date to exploit the classification of patent assignees provided by the USPTO. We started from the available USPTO classification and derived detailed categories on the type of patent owners (i.e., company, universities, research centers, individual, and the US government) by reading and aggregating the assignee names.

[20] Note that percentages sum up to more than 100% because patents may have multiple co-assignees and that the categorization is missing for 9% of cases.

[21] A potential loss might originate for the university in those cases in which patents are renewed until the last available year.

Table 7
timing of the licensing out according to the payment of the renewal fees for the sub-sample of patents with at least two renewals.

Time of licensing out (switch to the LES scheme)	Number of patents	Share of the total licensed patents
Before year 4	3342	84.4%
After year 4 and before year 8	528	13.3%
After year 8 and before year 12	92	2.3%

the selected US universities through the application of three sets of econometric models. The first type of analysis focuses on a comparison between patents in the portfolio of universities and the ones involved in any type of transaction. Our empirical model estimates the probability of a patent being transacted, on the condition that universities have paid the renewal fees of those patents (i.e., abandoned patents are not considered). Therefore, we are interested in the monetization choices of universities within the selected cohorts of granted patents that universities consider particularly valuable. We know, for each patent, whether it has been licensed or sold. In the first set of models, the dependent variable is the transaction event, which is equal to one if the patent is licensed or sold (zero if it is in the *residual group*). The logit models estimate the probability of a patent being transacted, conditional to the set of independent variables described in *Table 8*. The model specifications control for SIC sectors and time dummies that refer to the application year of the patents.

The second set of analyses provides further details on the characteristics of patents, according to the monetization channel, using a set of multinomial logit models. We consider three unordered categories of patents: *licensed, reassigned* (sold), and the *residual group*. In this second set of models, the dependent variable is the category indicator of the patent. The probability of a patent being licensed or sold is compared with the probability of the patent in the *residual group*, which is our baseline category. It is important to underline that again in this case, we exclude patents that have been abandoned and patents that have been re-assigned within a potential administrative procedure (see *Section 4.1*). The independent and the control variables are the same as those of the first step of the analysis and are reported in *Table 8*.

Since the monetization process is dynamic, in the third set of analyses we employ *Cox* proportional hazards models, where the failure event is the identification of a patent license. As explained in *Section 4*, the identification strategy does not determine a precise date for licenses, hence we considered them at the moment of a patent renewal (every four years after the grant).

With the aim of accounting for specific university characteristics, all the econometric specifications have been tested with standard errors that allow for intragroup correlation (each cluster being a single university). *Table 8* reports the label, the description and a number of summary statistics of the patent-level variables in the analyzed sample, which excludes administrative transactions and abandoned patents.

Table 9
descriptive statistics of the patent-level variables by commercialization outcome.

Variable	Transacted	Licensed out	Residual group
No. of assignees	1.139	1.301	1.109
	(0.403)	(0.537)	(0.349)
No. of inventors	3.012	3.368	2.813
	(1.891)	(1.930)	(1.514)
No. of claims	22.296	22.624	21.004
	(18.468)	(19.359)	(17.163)
No. of claims above twenty	6.813	7.501	6.243
	(15.799)	(16.327)	(13.874)
Tech. scope	2.157	2.724	2.332
	(1.523)	(1.843)	(1.517)
Bwd. cit.	27.414	25.193	17.102
	(46.645)	(39.051)	(29.436)
Science cit.	19.894	34.497	25.093
	(43.144)	(54.510)	(43.562)
Time-to-grant	41.903	42.610	42.077
	(18.265)	(21.294)	(19.215)
Geo. scope	4.867	6.937	4.193
	(4.563)	(6.435)	(4.244)
Fwd. cit.	59.795	41.652	26.862
	(141.426)	(73.819)	(51.828)
No. of words in the first ind. claim	129.692	115.606	115.025
	(84.929)	(83.619)	(95.455)
Patent in a core field	0.855	0.929	0.912
	(0.353)	(0.257)	(0.283)
Patent in a non-core field	0.353	0.216	0.227
	(0.479)	(0.412)	(0.419)

Note: the standard deviation of each variable is reported in parentheses.

Table 9 reports the raw averages and the standard deviations of the patent-level variables for the different commercialization outcomes (i.e., transacted, licensed out, and the residual group). *Table 12* in the *Appendix* shows the correlation matrix.

5.1. Results on the characteristics of transacted patents

The models from 1 to 5 in *Table 10* report the results of the logit specifications with standard errors clustered on the examined universities to account for the university level unobserved characteristics.

Transacted patents have a higher technical merit. They tend to be the

Table 8
descriptive statistics of the patent-level variables.

Label	Description	Obs.	Mean	Std. dev.	Min	Max
No. of assignees	Number of assignees associated to the granted patent	21,451	1.175	0.434	1	6
No. of inventors	Number of inventors associated to the granted patent	21,451	3.007	1.695	1	19
No. of claims	Number of claims	21,451	21.582	17.985	1	397
No. of claims above twenty	Number of claims that introduce extra filing fees. It is set to 0 when the number of claims is below 21	21,451	6.420	14.474	0	377
Tech. scope	Number of IPC sub-classes at three-digits	21,451	2.464	1.647	1	17
Bwd. cit.	Number of backward citations to patents	21,451	20.045	33.595	0	737
Science cit.	Number of backward citations to non-patent references	21,451	28.249	47.825	0	920
Time-to-grant	Number of months from application to grant	21,451	42.258	19.942	5	202
Geo. Scope	Number of filing countries of all the members in the patent family	21,451	5.148	5.272	0	51
Fwd. cit.	Number of forward citations to patents	21,451	32.460	62.959	0	1602
No. of words in the first ind. claim	Number of words in the first independent claim*	21,390	115.452	91.406	8	4264
Patent in a core field	Dummy equal to one if the patent is associated to at least one SIC field representing more than 10% of the university portfolio	21,451	0.917	0.276	0	1
Patent in a non-core field	Dummy equal to one if the patent is associated to at least one SIC field representing less than 10% of the university portfolio	21,451	0.226	0.418	0	1

* We dropped the information relating to the length of the first independent claim for 49 patents having a number of words less than or equal than 8. Additional details on the natural language processing technique used in order to build the variable can be found in the methodological appendix of Marco et al. (2019).

Table 10
logit models on the probability of a patent being transacted (licensed out or reassigned) with respect to be in the *residual group*.

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5
No. of assignees	0.788***	0.796***	0.800***	0.790***	0.794***
	(0.096)	(0.096)	(0.096)	(0.097)	(0.098)
No. of inventors	0.104***	0.098***	0.097***	0.108***	0.107***
	(0.018)	(0.017)	(0.017)	(0.018)	(0.018)
No. of claims	0.001	0.0004	0.001		
	(0.002)	(0.002)	(0.002)		
Tech. Scope	0.032	0.030	0.031		
	(0.023)	(0.023)	(0.023)		
Bwd cit.	0.004**	0.003**	0.003**		
	(0.002)	(0.002)	(0.002)		
Science cit.	0.0002	0.0002	0.0002	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Words in Ind.Cl.				0.0003	0.0003
				(0.0002)	(0.0002)
Time to grant	−0.007***	−0.006***	−0.006***	−0.007***	−0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Geo. Scope	0.092***	0.090***	0.090***	0.098***	0.098***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Fwd cit.		0.002***	0.002***		
		(0.001)	(0.001)		
Patent in a core field	0.045	0.040		0.044	
	(0.201)	(0.200)		(0.202)	
Patent in a non-core field			−0.335**		−0.336**
			(0.136)		(0.133)
Appl. Year dummies	Y	Y	Y	Y	Y
SIC sector dummies	Y	Y	Y	Y	Y
Observations	21,447	21,447	21,447	21,428	21,428
Log Likelihood	−12,661	−12,635	−12,617	−12,678	−12,659

Note: robust clustered standard errors are in parentheses; the significance levels are *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

result of larger projects with a relatively higher number of assignees and inventors. The marginal effects of these variables indicate an increase in the likelihood of transactions of 16% and 2% for any additional assignee and inventor respectively. The other measures of patent importance – the number of forward citations and the geographical scope – are significant and positively related to the likelihood of monetization. The marginal effect of an additional country in the patent family is 2%, while a single forward citation is associated to an increase of only 0.03%. The number of words in the first independent claim, a measure of the patent scope, is not significant and has a very small coefficient.

Furthermore, patents in sectors where the university produces less inventions appear less likely to be transacted (a decrease of 7%), thus suggesting a limited knowledge of the market or the presence of a narrower network of links with the players in that technological field.

Transacted patents are legally robust. They show a significant positive correlation with the number of backward citations and, as emphasized above, with the geographical scope. However, the marginal effect of a single additional citation is negligible (increase of 0.06%). The number of claims and of words in the first independent claim are positively related but not significant.

Complexity, measured in terms of large research teams, does not seem to be an obstacle to monetization. The number of technological classes that proxies the technological scope is not significant. In addition, transacted patents are, on average, granted quicker, suggesting that the time-to-grant can be a source of technological uncertainty and can hinder the monetization process.[22] However, one further month between patent filing and issuance is associated to a mere 0.1% decrease in the likelihood of observing a transaction.

Finally, the measure of basicness – the count of backward non-patent citations – is positively related to monetization, but it is not significant and has a very small coefficient.

We performed several robustness checks and reported them in the Appendix. *Table A1* shows the results when we excluded the *bwd cit.* variable (as suggested in the recent work of Kuhn et al., 2020) and tested different model specifications by replacing the number of claims with the variable *claims above twenty*. Furthermore, we analyzed two different samples of patents: the first one considers the administrative reassignments together with the patents included in the residual group (*Table A2*); the second one focuses on the subgroup of patents that have been renewed at least twice, i.e. representing the inventions considered of high relevance by universities (*Table A3*). In all cases, the results are very similar to the ones reported in *Table 9*.

5.2. Differences across monetization channels

Table 11 shows the results of the multinomial logit models with standard errors clustered on the examined universities to account for any unobserved university-level characteristics. The reference group includes the patents that have not been transferred from the university to a third party (i.e., the *residual group*).

The aggregate evidence is that: licensed patents are significantly different from those in the *residual group* over several dimensions, while patents reassigned to companies and NPEs differ from non-transacted ones mainly because of their higher technical merit and legal robustness.

The measures of patent importance and technical merit, i.e. the forward citations and geographical scope, are significant and positively related to both channels of monetization. Moreover, both the number of assignees and the number of inventors are larger for licensed patents than for those in the *residual group*. When comparing reassigned patents with the *residual group*, the number of assignees is positively related but not significant, while the number of inventors is slightly significant only in some models (1 and 4). The marginal contributions of a unit increase to licensing likelihood for the variables is the following: number of inventors +2%, number of assignees +16%, geographical scope +2%, forward citations 0.03%; the contributions to reassignment likelihood

[22] This effect might also be related to the implementation of AIPA in 1999 and the 18-months limit for publication of applications (Drivas et al., 2018). In this light, a negative effect might reflect that patents with a longer time to grant have likely been exposed for a longer time to pre-granting contracting and hence they are likely, ceteris paribus, to be less licensable at grant than another application with a shorter time to grant.

Table 11
multinomial logit models on the probability of a patent being licensed or reassigned (to companies or NPEs), comparison with patents in the *residual group*.

VARIABLES	Model 1 Licensed	Reassign.	Model 2 Licensed	Reassign.	Model 3 Licensed	Reassign.	Model 4 Licensed	Reassign.
No. of assignees	0.807***	0.184	0.814***	0.211	0.818***	0.207	0.813***	0.194
	(0.100)	(0.209)	(0.099)	(0.210)	(0.099)	(0.210)	(0.101)	(0.206)
No. of inventors	0.105***	0.081*	0.100***	0.068	0.098***	0.068	0.107***	0.088**
	(0.018)	(0.043)	(0.018)	(0.045)	(0.017)	(0.045)	(0.018)	(0.043)
No. of claims	0.001	−0.004	0.001	−0.005	0.001	−0.005		
	(0.002)	(0.005)	(0.002)	(0.005)	(0.002)	(0.005)		
Tech. Scope	0.035	−0.067	0.033	−0.073	0.034	−0.076		
	(0.024)	(0.073)	(0.024)	(0.073)	(0.023)	(0.075)		
Bwd cit.	0.003*	0.008***	0.003*	0.007***	0.003*	0.007***		
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)		
Science cit.	0.0003	−0.005	0.0003	−0.005	0.0003	−0.005	0.001	−0.001
	(0.001)	(0.004)	(0.001)	(0.004)	(0.001)	(0.004)	(0.001)	(0.004)
Words in Ind.Cl.							0.0003	0.001**
							(0.0003)	(0.0004)
Time to grant	−0.007***	−0.004	−0.006***	−0.003	−0.006***	−0.003	−0.007***	−0.004
	(0.001)	(0.005)	(0.001)	(0.005)	(0.001)	(0.005)	(0.001)	(0.005)
Geo. Scope	0.093***	0.070***	0.091***	0.065***	0.091***	0.065***	0.099***	0.076***
	(0.012)	(0.025)	(0.012)	(0.024)	(0.012)	(0.024)	(0.011)	(0.025)
Fwd cit.			0.002***	0.003***	0.002***	0.003***		
			(0.001)	(0.001)	(0.001)	(0.001)		
Patent in a core field	0.064	−0.136	0.059	−0.143				
	(0.214)	(0.273)	(0.214)	(0.278)				
Pat. in a non-core field					−0.374***	0.291	−0.375***	0.263
					(0.143)	(0.312)	(0.141)	(0.312)
Appl. Year dummies	Y	Y	Y	Y	Y	Y	Y	Y
SIC sector dummies	Y	Y	Y	Y	Y	Y	Y	Y
Observations	21,451		21,451		21,451		21,432	
LogLlikelihood	−13,893		−13,866		−13,842		−13,892	

Note: robust clustered standard errors are in parentheses; the significance levels are *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

are very small (between 0.03% and 0.04%). The number of words in the first independent claim is positively related and significant only for the group of reassignments when compared to the *residual group* but the marginal effect is negligible (+0.1% for additional 100 words).

There is evidence that inventions in marginal fields of the university's technological portfolio are less likely to be licensed out (marginal effect of −8%).

Moreover, both types of transacted patents are positively related to the number of backward citations, even if the marginal effect is of limited magnitude (+0.05% for licensing likelihood and +0.01% for reassignment). The results confirm the previous finding that granted patents with a higher number of backward references and a larger geographical scope, and thus with a higher legal robustness, are positively associated with the likelihood of monetization for any type of transaction.

As far as the measures of technological complexity are concerned, the reassigned patents do not seem to be significantly different from those in the *residual group*. The largest part of the variance identified in the previous set of multivariate analyses seems to derive from the difference between licensed and patents in the *residual group*. Patents scope, as proxied by the number of claims, of IPC codes o of words in the first independent claim, is not statistically different across the types of monetization. Licensed patents are on average granted in less time and the difference is significant; however, one month delay is associated to a mere −0.1% to the licensing likelihood. Science basicness proxied by backward non-patent citations does not report significant coefficients.

We reported several robustness analyses in the Appendix. *Table A4* tests the exclusion of the variable *bwd cit.* (following Kuhn et al., 2020) and the significance of the variable *claims above twenty*. No significant result is found for the latter and the coefficients are robust to these changes in the model specifications.[23] Furthermore, we analyzed two different samples of patents. *Table A5* shows the results on the sample of patents that consider the administrative reassignments in the *residual group*: the results are very similar. As an additional analysis and robustness check, we tested the models on the sub-sample of patents that have been renewed at least twice. The results are reported in Table A6 of the Appendix and are very similar to those found for the whole sample: for this subset of patents the differences between those in fields core to the university and those in marginal technological areas are more pronounced. Reassignment events are more likely to be associated to patent in no-core fields, while the opposite is found for licensing. The analysis lends support to the presence of differences between the two types of monetization channels.

5.3. Survival models

The analysis of the transaction likelihood considering the evolution of the risk to observe a license agreement or a reassignment confirms that, on average, the hazard rate is higher in the early years and decreases with time. We underline again that in our dataset the precise date of licensing is not available, and we infer it on the renewal dates every four years. *Table 12* reports the results of the Cox proportional hazards models where the failure event is to observe a patent license (coefficients are reported). The results are very similar to those in the static model with two exceptions: the variable time-to-grant is still negative but not always significant, the technological scope is positively associated to the likelihood of being licensed.

Positive signs indicate accelerated time to transaction at the increase of the variable: number of assignees, of inventors, and of IPC classes (measures of technological complexity), number of backward citations (indicators of legal robustness), geographical scope (proxy of legal robustness and value), and number of forward citations (proxy of value).

[23] We do not think that the additional costs raised by the extra fees could significantly influence the decision process with respect to the value of the invention in our case. Van Pottelsberghe and François (2009) estimated that on average the claim tax is 2% of the procedural costs, and translation, attorneys, (*footnote continued*) and international extensions must be added. The relatively small additional amount on the total patenting cost of academic inventions is not expected to oblige the inventors or the attorneys to re-draft their filing according to the expected future value of the invention.

Table 12
survival models on the probability of a patent being licensed out with respect to be in the *residual group*.

VARIABLES	Model 1	Model 2	Model 3	Model 4
No. of assignees	0.388***	0.392***	0.382***	0.387***
	(0.046)	(0.046)	(0.047)	(0.047)
No. of inventors	0.049***	0.048***	0.055***	0.053***
	(0.008)	(0.008)	(0.008)	(0.008)
No. of claims	0.001	0.001		
	(0.001)	(0.001)		
Tech. Scope	0.025**	0.025**		
	(0.013)	(0.012)		
Bwd cit.	0.001**	0.001**		
	(0.001)	(0.001)		
Science cit.	0.0001	0.0001	0.001	0.001*
	(0.0004)	(0.0003)	(0.0004)	(0.0004)
Words in Ind.Cl.			0.0002	0.0002
			(0.0001)	(0.0001)
Time to grant	−0.001	−0.001	−0.001*	−0.001*
	(0.001)	(0.001)	(0.001)	(0.001)
Geo. Scope	0.040***	0.040***	0.043***	0.043***
	(0.004)	(0.004)	(0.004)	(0.004)
Fwd cit.	0.001***	0.001***		
	(0.0002)	(0.0002)		
Patent in a core field	0.046		0.044	
	(0.137)		(0.138)	
Patent in a non-core field		−0.221***		−0.218***
		(0.081)		(0.079)
Appl. Year dummies	Y	Y	Y	Y
SIC sector dummies	Y	Y	Y	Y
Observations	21,120	21,120	21,101	21,101
No. of failures	7382	7382	7382	7382
Time at risk	137,555	137,555	137,426	137,426
Log Likelihood	−71,962	−71,948	−71,984	−71,971
Chi2	150,124	70,231	18,187	13,278

Note: robust clustered standard errors are in parentheses; the significance levels are *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A7 in the Appendix reports the results of robustness tests with the inclusion of the variable *claims above twenty*, not significant, and excluding the number of backward citations. The econometric analyses show coefficients that are similar to those in *Table 11*.

6. Conclusion

This study has investigated the composition of the patent portfolios of the main universities in the US for the years from 2002 to 2010 with the aim of estimating the magnitude of the monetization activities at the patent level and of exploring the relationship between the characteristics of the transacted inventions and the likelihood of observing a license or a reassignment. The novelty of this study lies in the simultaneous application of diverse methods, which were developed in previous studies (De Marco et al., 2017; Drivas et al., 2016; Serrano, 2010), to identify the different transaction types of patented innovations in US university portfolios.

The obtained data show that 63.0% of the considered patents have never been involved in any form of transaction. Around 29.7% of the inventions have been licensed out; 5.9% have been reassigned to other universities, national laboratories, federal agencies or other non-profit entities; 1.3% of the patents have been reassigned to a company or a NPE.

Licensing occurs in most of the cases before the first renewal payment, that is, before year 4: inventions with potential target licensees are marketed not long after the grant or even before (Drivas et al., 2017). Patent sales seem to represent a marginal activity, in terms of number of events, although a slightly increasing trend has been observed. The reassignment transactions involve more than two thirds of the universities in the sample, which marketed on average 5.7 patents.

We study four characteristics of patents, related to different types of technological or economic uncertainty that affect the transaction likelihood of university inventions: patent value or technical merit, legal robustness, technological complexity and science basicness. We have identified a number of patent bibliometrics to proxy these characteristics.

The patent bibliometrics were studied in three sets of econometric models. First, we compared the transacted patents and those in the *residual group*; second, we compared patents in the *residual group* with those from each monetization channel, i.e. licensing out and reassignment as a result of sale; third, we introduced survival model analyses to analyze the dynamic nature of the monetization process.

The combined analysis of the bibliometric indicators suggests that transacted patents are positively associated with the importance or technical merit of the protected inventions, and with a higher legal robustness. The market for technology seems to work as expected along these two dimensions, and to favor the diffusion of valuable and legally sound inventions, i.e. those characterized by a lower uncertainty level.

As far as the *complexity* dimension is concerned, we find a higher likelihood of monetization when there are multiple assignees and with larger teams of inventors. This result might be partly driven by the presence of the licensee as an original research collaborator or sponsor but it also suggests that technology acquirers are in particular interested in those inventions that require access to a non-trivial number of resources that might combine multiple skills and knowhow in the same technological field. In fact, the non-significant result for the technological scope suggests that a broad coverage of fields is not a sufficient condition to increase the chances of observing a transaction. The negative result in terms of duration of examination procedure is not robust to the survival econometric analysis.

Basicness does not seem to limit monetization, unlike what has been observed for corporate patents (Caviggioli and Ughetto, 2013). We argue that those technology acquirers who look at university patent portfolios as a technological source are aware of the type of development level of the inventions of interest.

From the university TTO perspective, our findings could provide indications to support the decisions on grants and renewal fee payments, in order to favor legally sound patents and pay attention to patents whose examination process was not straightforward and longer than the average.

In addition, we find that there are differences among the *residual group*, licensed and sold patents. Licensed patents are different from the *residual group* along several dimensions: higher value, higher legal robustness and higher complexity. Patents reassigned to companies and NPEs seem to differ for their higher technical merit. The proxies of technological complexity do not seem to differ between reassigned and patents in the *residual group*. This evidence, in combination with the summary statistics on the limited frequency of reassignment events, suggests that the sales channel is somewhat accidental, but it nevertheless succeeds in selecting those inventions with higher technical merit than those remaining on the university shelves.

Our work has an exploratory nature and it is not exempt from limitations. The identification strategy is based on the applications of the methods outlined in Drivas et al. (2016), De Marco et al. (2017) and Serrano (2010), and consequently incorporates their limitations. In particular, licensing events are captured from a change in the type of renewal fee, which may occur only at four-year intervals after the patent issuance (and most occur at the first deadline). In this regard, having an exact date of the transaction as well as additional information on the entity size at grant would provide useful data to study the proportion of patents that is already licensed before the first maintenance fee and further improve the analysis on the timing of commercialization. Furthermore, the current data on the transactions do not include any information on the monetary agreements (royalties, lump sums, or more complex schemes). Finally, future research could extend the time and the geographical framework of the analyses outside the US.

CRediT authorship contribution statement

Federico Caviggioli: Conceptualization, Methodology, Formal analysis, Visualization, Validation, Writing - original draft, Writing - review & editing, Supervision. **Antonio De Marco:** Conceptualization, Methodology, Data curation, Visualization, Writing - original draft, Writing - review & editing. **Fabio Montobbio:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing, Validation. **Elisa Ughetto:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.techfore.2020.120189.

Appendix

Tables A1, A2, A3, A4, A5, A6, A7, A8

Table A1
correlation matrix.

	No. ofassignees	N. ofinventors	N. ofclaims	Claimsabove twenty	Tech.scope	Backwardcit.	Sciencecit.	Words inind. cl.	Time togrant	Geo.scope	Fwdcit.	Corepatent
N. of inventors	0.312											
N. of claims	0.0003	0.034										
Claims above twenty	0.004	0.037	0.949									
Tech. scope	0.061	0.111	−0.018	0.015								
Backward cit.	0.073	0.091	0.121	0.107	0.097							
Science cit.	0.109	0.084	0.059	0.073	0.209	0.446						
Words in ind. cl.	−0.006	−0.006	0.068	0.043	−0.077	0.059	−0.038					
Time-to-grant	0.034	0.036	−0.005	0.016	0.158	0.058	0.185	0.031				
Geo. scope	0.156	0.122	0.046	0.072	0.350	0.267	0.328	−0.047	0.104			
Fwd cit.	−0.005	0.088	0.181	0.160	0.029	0.150	0.020	0.045	−0.050	0.082		
Core patent	0.022	0.029	−0.028	−0.009	0.200	0.030	0.097	−0.079	0.028	0.147	−0.002	
Patent in a no-core field	−0.018	0.004	0.060	0.037	0.135	0.044	−0.049	0.044	−0.011	−0.062	0.029	−0.490

Table A2
logit model on the probability of a patent being transacted (licensed out or reassigned), comparison with patents in the residual group.

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
N. of assignees	0.798***	0.802***	0.796***	0.800***	0.798***	0.801***	0.790***	0.794***
	(0.096)	(0.096)	(0.096)	(0.096)	(0.096)	(0.096)	(0.097)	(0.097)
N. of inventors	0.099***	0.098***	0.098***	0.097***	0.099***	0.098***	0.106***	0.104***
	(0.018)	(0.017)	(0.017)	(0.017)	(0.018)	(0.017)	(0.017)	(0.017)
N. of claims	0.001	0.001						
	(0.002)	(0.002)						
Claims above twenty			−0.0001	−0.0001	0.0001	0.0002	0.001	0.001
			(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Tech. scope	0.032	0.033	0.030	0.031	0.032	0.033		
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)		
Bwd cit.			0.003**	0.003**			0.004**	0.004**
			(0.002)	(0.002)			(0.002)	(0.002)
Science cit.	0.001	0.001	0.0002	0.0002	0.001	0.001	0.0002	0.0002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Words in ind. cl.							0.0003	0.0003
							(0.0003)	(0.0003)
Time-to-grant	−0.006***	−0.006***	−0.006***	−0.006***	−0.006***	−0.006***	−0.007***	−0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Geo. scope	0.094***	0.093***	0.090***	0.090***	0.094***	0.093***	0.093***	0.093***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.011)
Fwd cit.	0.002***	0.002***	0.002***	0.002***	0.002***	0.002***		
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)		
Patent in a core field	0.044		0.040		0.044		0.039	
	(0.202)		(0.200)		(0.202)		(0.200)	
Patent in a no-core field		−0.332**		−0.334**		−0.331**		−0.339**
		(0.135)		(0.136)		(0.135)		(0.135)
Appl. year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SIC sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,447	21,447	21,447	21,447	21,447	21,447	21,428	21,428
Log-likelihood	−12,652	−12,634	−12,636	−12,618	−12,652	−12,634	−12,655	−12,636

Note: robust clustered standard errors are in parentheses; the significance levels are *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A3
logit model on the probability of a patent being transacted (licensed out or reassigned), comparison with patents in the *residual group* (including *administrative transactions*).

VARIABLES	Model 1	Model 2
N. of assignees	0.781***	0.784***
	(0.096)	(0.096)
N. of inventors	0.083***	0.082***
	(0.024)	(0.024)
N. of claims	0.001	0.001
	(0.001)	(0.001)
Tech. scope	0.035	0.036
	(0.025)	(0.025)
Bwd cit.	0.003**	0.003**
	(0.002)	(0.002)
Science cit.	0.0003	0.0004
	(0.001)	(0.001)
Time-to-grant	−0.005***	−0.005***
	(0.002)	(0.002)
Geo. scope	0.094***	0.094***
	(0.011)	(0.010)
Fwd cit.	0.002***	0.002***
	(0.001)	(0.001)
Patent in a core field	0.011	
	(0.210)	
Patent in a no-core field		−0.291**
		(0.142)
Appl. year dummies	Yes	Yes
SIC sector dummies	Yes	Yes
Observations	22,826	22,826
Log-likelihood	−13,138	−13,124

Note: robust clustered standard errors are in parentheses; the significance levels are *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A4
logit model on the probability of a patent being transacted (licensed out or reassigned), tested on the sub-sample of patents renewed at least twice, comparison with patents in the *residual group*.

VARIABLES	Model 1	Model 2
No. of assignees	0.634***	0.641***
	(0.093)	(0.095)
No. of inventors	0.095***	0.093***
	(0.023)	(0.023)
No. of claims	−0.0005	−0.0004
	(0.002)	(0.002)
Tech. scope	0.027	0.030
	(0.029)	(0.030)
Bwd cit.	0.005**	0.005**
	(0.002)	(0.002)
Science cit.	0.001	0.001
	(0.001)	(0.001)
Time-to-grant	−0.005***	−0.005***
	(0.002)	(0.002)
Geo. scope	0.074***	0.074***
	(0.014)	(0.014)
Fwd cit.	0.001**	0.001**
	(0.001)	(0.001)
Patent in a core field	−0.049	
	(0.220)	
Patent in a non-core field		−0.251
		(0.168)
Appl. year dummies	Yes	Yes
SIC sector dummies	Yes	Yes
Observations	9796	9796
Log-likelihood	−6138	−6133

Note: robust clustered standard errors are in parentheses; the significance levels are *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A5
multinomial logit models on the probability of a patent being licensed or reassigned (to companies or NPEs), comparison with patents in the *residual group*.

	Model 1		Model 2		Model 3		Model 4	
VARIABLES	**Reassigned**	**Licensed**	**Reassigned**	**Licensed**	**Reassigned**	**Licensed**	**Reassigned**	**Licensed**
N. of assignees	0.210	0.814***	0.206	0.818***	0.216	0.816***	0.212	0.820***
	(0.210)	(0.099)	(0.211)	(0.099)	(0.207)	(0.099)	(0.209)	(0.100)
N. of inventors	0.068	0.100***	0.068	0.098***	0.073	0.100***	0.073	0.099***
	(0.045)	(0.018)	(0.045)	(0.017)	(0.045)	(0.018)	(0.046)	(0.018)
Claims above twenty	−0.007	0.0002	−0.007	0.0003	−0.006	0.0004	−0.006	0.0005
	(0.006)	(0.002)	(0.006)	(0.002)	(0.006)	(0.002)	(0.006)	(0.002)
Tech. scope	−0.073	0.033	−0.075	0.034	−0.072	0.034	−0.075	0.035
	(0.073)	(0.024)	(0.075)	(0.023)	(0.074)	(0.024)	(0.076)	(0.023)
Bwd cit.	0.007***	0.003*	0.007***	0.003*				
	(0.002)	(0.002)	(0.002)	(0.002)				
Science cit.	−0.005	0.0003	−0.005	0.0003	−0.002	0.001	−0.002	0.001
	(0.004)	(0.001)	(0.004)	(0.001)	(0.004)	(0.001)	(0.004)	(0.001)
Time-to-grant	−0.003	−0.006***	−0.003	−0.006***	−0.002	−0.006***	−0.002	−0.006***
	(0.005)	(0.001)	(0.005)	(0.001)	(0.005)	(0.001)	(0.005)	(0.001)
Geo. scope	0.065***	0.091***	0.065***	0.091***	0.075***	0.095***	0.074***	0.094***
	(0.024)	(0.012)	(0.024)	(0.012)	(0.024)	(0.012)	(0.024)	(0.011)
Fwd cit.	0.003***	0.002***	0.003***	0.002***	0.003***	0.002***	0.003***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Patent in a core field	−0.142	0.059			−0.136	0.063		
	(0.277)	(0.214)			(0.285)	(0.215)		
Pat. in a no-core field			0.291	−0.373***			0.298	−0.371***
			(0.311)	(0.143)			(0.313)	(0.142)
Appl. year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SIC sector dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,451	21,451	21,451	21,451	21,451	21,451	21,451	21,451
Log-likelihood	−13,866	−13,866	−13,842	−13,842	−13,887	−13,887	−13,864	−13,864

Note: robust clustered standard errors are in parentheses; the significance levels are *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A6
multinomial logit models on the probability of a patent being licensed or reassigned (to companies or NPEs), comparison with patents in the *residual group* (including *administrative transactions*).

	Model 1		Model 2	
VARIABLES	Reassigned	Licensed	Reassigned	Licensed
N. of assignees	0.223	0.798***	0.220	0.802***
	(0.205)	(0.099)	(0.205)	(0.099)
N. of inventors	0.048	0.085***	0.049	0.084***
	(0.048)	(0.024)	(0.048)	(0.024)
N. of claims	−0.004	0.002	−0.004	0.002
	(0.005)	(0.001)	(0.005)	(0.001)
Tech. scope	−0.068	0.037	−0.070	0.039
	(0.074)	(0.026)	(0.075)	(0.026)
Bwd cit.	0.007***	0.003*	0.007***	0.003*
	(0.002)	(0.002)	(0.002)	(0.002)
Science cit.	−0.004	0.0002	−0.004	0.001
	(0.004)	(0.001)	(0.004)	(0.001)
Time-to-grant	−0.002	−0.005***	−0.002	−0.005***
	(0.005)	(0.002)	(0.005)	(0.002)
Geo. scope	0.072***	0.095***	0.071***	0.095***
	(0.021)	(0.011)	(0.021)	(0.010)
Fwd cit.	0.003***	0.002***	0.003***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)
Patent in a core field	−0.162	0.029		
	(0.278)	(0.223)		
Pat. in a no-core field			0.327	−0.331**
			(0.322)	(0.149)
Appl. year dummies	Yes	Yes	Yes	Yes
SIC sector dummies	Yes	Yes	Yes	Yes
Observations	22,830	22,830	22,830	22,830
Log-likelihood	−14,370	−14,370	−14,350	−14,350

Note: robust clustered standard errors are in parentheses; the significance levels are *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A7
multinomial logit models on the probability of a patent being licensed or reassigned (to companies or NPEs) for the sub-sample of patents with at least two renewals, comparison with patents in the *residual group*.

VARIABLES	Model 1 Reassigned	Licensed	Model 2 Reassigned	Licensed
N. of assignees	−0.037	0.656***	−0.043	0.663***
	(0.303)	(0.097)	(0.298)	(0.098)
N. of inventors	0.071	0.096***	0.071	0.094***
	(0.068)	(0.023)	(0.068)	(0.023)
N. of claims	−0.008	−0.0002	−0.008	−0.0002
	(0.006)	(0.002)	(0.006)	(0.002)
Tech. scope	−0.101	0.031	−0.099	0.033
	(0.094)	(0.029)	(0.099)	(0.030)
Bwd cit.	0.008**	0.004**	0.008***	0.005**
	(0.003)	(0.002)	(0.003)	(0.002)
Science cit.	−0.008	0.001	−0.008	0.001
	(0.009)	(0.001)	(0.009)	(0.001)
Time-to-grant	−0.002	−0.005***	−0.002	−0.005***
	(0.007)	(0.002)	(0.007)	(0.002)
Geo. scope	0.057*	0.075***	0.056*	0.075***
	(0.032)	(0.013)	(0.031)	(0.013)
Fwd cit.	0.003**	0.001**	0.003**	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)
Patent in a core field	−0.593*	0.011		
	(0.356)	(0.233)		
Pat. in a no-core field			0.787**	−0.330*
			(0.398)	(0.174)
Appl. year dummies	Yes	Yes	Yes	Yes
SIC sector dummies	Yes	Yes	Yes	Yes
Observations	9814	9814	9814	9814
Log-likelihood	−6836	−6836	−6822	−6822

Note: robust clustered standard errors are in parentheses; the significance levels are *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A8
survival models on the probability of a patent being licensed out with respect to be in the *residual group*.

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
No. of assignees	0.388***	0.392***	0.388***	0.392***	0.388***	0.392***
	(0.047)	(0.046)	(0.046)	(0.046)	(0.047)	(0.046)
No. of inventors	0.049***	0.048***	0.049***	0.048***	0.049***	0.048***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
No. of claims	0.001	0.001				
	(0.001)	(0.001)				
Claims above twenty			0.0003	0.0004	0.0004	0.0005
			(0.001)	(0.001)	(0.001)	(0.001)
Tech. scope	0.026**	0.026**	0.025**	0.025**	0.026**	0.026**
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Bwd cit.			0.001**	0.001**		
			(0.001)	(0.001)		
Science cit.	0.001	0.001	0.0001	0.0001	0.001	0.001
	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Words in ind. cl.						
Time-to-grant	−0.001	−0.001	−0.001	−0.001	−0.001	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Geo. scope	0.042***	0.042***	0.040***	0.040***	0.042***	0.042***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Fwd cit.	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Patent in a core field	0.048		0.046		0.048	
	(0.138)		(0.137)		(0.138)	
Patent in a non-core field		−0.217***		−0.220***		−0.216***
		(0.080)		(0.081)		(0.080)
Appl. year dummies	Yes	Yes	Yes	Yes	Yes	Yes
SIC sector dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,120	21,120	21,120	21,120	21,120	21,120
No. of failures	7382	7382	7382	7382	7382	7382
Time-at-risk	137,555	137,555	137,555	137,555	137,555	137,555
Log-likelihood	−71,970	−71,957	−71,962	−71,949	−71,970	−71,957
Chi-squared	63,867	33,174	65,204	78,832	70,975	35,155

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