University Technology Transfer Office Business Models: One Size Does Not Fit All

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University Technology Transfer Business Models:
One Size does NOT Fit All

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Abstract. Technology transfer processes enable universities to increase their positive impact on society by pursuing their entrepreneurial mission in several ways. By analyzing quantitative and qualitative data collected in a longitudinal dataset of 60 U.S. universities during the period 2002-2012, this article identifies four types of technology transfer business models that may generate economic and non-economic linkages that need to be evaluated. Findings reveal that business models that leverage high-quality research (i.e., catalyst) and startup creation (i.e., orchestrator of local buzz) are associated with higher economic performance. This study contributes to the emergent literature on university business models and provides suggestions to policymakers to incorporate a business model typology in university evaluation programs.

1. Introduction

It is widely recognized that the Bayh-Dole Act of 1980 led to an explosion in the commercialization of university inventions and academic spawning of new innovative firms (Feldman, 2003, Siegal et *al.* 2007) and, more generally, an increase in activities promoting academic entrepreneurship (see Grimaldi et *al.*, 2011). As a result, the diffusion of knowledge from universities to industry has emerged as an important (third) mission of universities (Rasmussen et *al.* 2006; Thursby et *al*., 2001), crucial to support national competitiveness and economic growth. Creating positive impacts through science commercialization is one of the most prominent policy goals that universities have incorporated in their strategic plans. To achieve this goal, universities have become more entrepreneurial, devoting their organizational efforts to patenting activities, enlarging their business network, and more generally enriching technology transfer channels, including startup formation. This is often achieved by establishing a technology transfer office (TTO), which is responsible for shaping the university's technology transfer "business model" by configuring this broad range of mechanisms. Accordingly, one cas ask: *Which types of business models are associated with the strategic goals and initiatives adopted by universities to pursue their technology transfer activities and with which related outputs?*

The core idea behind this research question is that university technology transfer may be targeted to meet multiple stakeholders' needs and these are prominent to evaluate technology transfer effectiveness. While research and teaching are institutional activities comparable among universities, technology transfer activities are influenced by several strategic goals at the university level ranging from having a positive impact on society to increasing economic income. Data from the United States show that between 2002 and 2009, the number of invention disclosures grew by 44% (National Science Board, 2012), and licensing revenues increased by almost 75% (AUTM, 2012), producing a potentially high impact on society. On the contrary, very few universities profit from high licensing income. This means that universities may choose the role they would like to play in society and which activities they want to pursue to promote economic growth. Taken together, universities may want to organize their technology transfer activities by taking a configurational view (Wiklund and Shepherd, 2005) and to choose how to "profit" from their research according to their strategic goals. In other words, universities can choose their technology transfer business model, seen as a unifying construct for explaining how they create and capture value from science (Baden-Fuller and Haefliger, 2013; Massa et al., 2017).

Prior work on university technology transfer largely neglects the business model lens, with a few exceptions. Miller et *al.* (2014) suggest that university business models are evolving activity systems, shaped by multiple stakeholders (e.g., academics, TTO managers, provosts and delegates, government representatives). University business models are also characterized by a broader engagement with society (Cesaroni and Piccaluga, 2015) and are gradually substituting models more focused on licensing agreements (Mets, 2010) or academic spinoffs (Dottore et *al.,* 2010). Taken together, prior work sheds light on a variety of university technology transfer activities and, in a few cases, stresses the relevance of adopting a business model perspective. But which types of business models universities may adopt in technology transfer and how they differ are still an under-researched topic that calls for more scholarly attention.

To address this question, an inductive examination of a sample of U.S. universities using quantitative and qualitative data (cf. Edmondson and McManus, 2007) was undertaken. Based on a longitudinal dataset of U.S. universities created by retrieving secondary data from the AUTM database (Association of University Technology Managers, http://www.autm.net/), a discriminant analysis leading to the identification of TTO strategic sub-groups was performed. This analysis was complemented with a variety of other sources of qualitative information stemming from universities' annual reports, press releases, as well as videos of presidents' or deans' speeches addressing missions and values. Such secondary data are also enriched with primary data generated from in-depth interviews with university provosts, TTO senior managers, and scientists, as well as AUTM workshop participants. The combined use of quantitative (secondary) and qualitative (primary and secondary) information corroborates the empirical analysis, whose robustness is confirmed via use of a standard statistical correlation and variance analyses.

The contributions of this study can be summarized as follows. First, the study contributes to the emergent literature on university business models (Dottore et *al.,* 2010; Mets, 2010; Miller et *al*., 2014; Cesaroni and Piccaluga, 2015) by highlighting four different types of technology transfer business models, relating single components and linkages with the other two university value propositions as well (teaching and research) and complementing current (and scarce) empirical findings based on European university settings. Second, this study provides concrete alternatives that inform a broader evaluation of technology transfer. Understanding how many technology transfer business models are empirically adopted by universities provides a more relevant basis for deriving policy implications than simply ranking the characteristics of successful institutions. This study is also consistent with the increasing attention to "public value" criteria, recently echoed by some scholars, who decry purely monetary values and highlight the importance of balancing economic metrics and non-monetary benefits (Sorensen and Chambers, 2008). Third, the findings of this study suggest that business models should properly accommodate reward systems for the engagement of top scientists and principal investigators who play several academic roles (Jain, George et *al.* 2009**;** Cunningham et *al.*, 2015), including indeed activities outside formal university channels (Perkmann et *al.*, 2015).

The remainder of this article is organized as follows. Section 2 presents a brief theoretical background on university technology transfer, and outlines the key drawbacks of evaluating university economic impact as well as the challenges of applying the business model concept in this debate. Section 3 contains the methodological approach proposed herein and the related findings. Section 4 presents the framework for classifying the business models of university TTOs. Section 5 contains a discussion of the findings, deriving their suggestions for researchers, managers, and policy-makers. Section 6 concludes by suggesting implications, limitations, and avenues for future research.

2. Theoretical Background

2.1 University technology transfer activities

Over the last decades, technology transfer has been seen as playing an increasingly significant role in stimulating innovation and economic development (Siegel, Waldman, and Link, 2003). Universities, especially after the passage of the Bayh-Dole Act of 1980, have increased their efforts in bringing innovative ideas and inventions to market, specially supporting commercialization of federally-funded research, by established Technology Transfer Offices (Friedman and Silberman, 2003) to support licensing activities and other forms of intellectual property (IP) resulting from university research (Siegel, Waldman, Atwater, and Link, 2004). As a result, the number of university patent applications has risen considerably. Drawing upon data from the U.S. Patent and Trademark Office (USPTO), the number of patents awarded to U.S. universities has increased from 1,925 patents in 1995 to around 3,000 by the late 2000s. This increase represents not only the effect of U.S. university patenting but it includes also universities in countries such as China and Japan that have started to file patents at the USPTO, since the U.S. has a highly competitive market for high-tech innovations. Thus, the number of university patents is widely accepted as one indicator of technology transfer performance (Kim et *al.,* 2012). Of course, this improvement comes with some tensions and conflicts between universities and industry, as well as between universities themselves and their own researchers. Traditionally, university academics are interested to the pursuit of some combination of the three Fs: *fame*, *fortune, and freedom*, which means publications, citations, prestige and professional awards (Dasgupta and David, 1994; Merton, 1973). The behavior and reward system for academics changed after the passage of Bayh-Dole Act, since publications and scientific dissemination can compromise patent applications. On the other hand, monetary benefits from patenting and licensing are of great concern between university management and industry and sometimes they are sources of coopetitive tensions (Baglieri, 2009). Taken together, these conflicts highlight a growing shift from a pure "public good" knowledge regime to a more "academic capitalist" knowledge regime (Slaughter and Rhoades, 2004). In fact, the key consequence of this normative change is that institutional and normative boundaries between the two epistemic communities blurred. To balance these potential conflicts, the technology transfer offices (TTOs) have had to build their legitimacy with respect to academic scientists, by preserving academic freedom, creating and diffusing knowledge, and to the university managers who are interested in industry collaboration (O'Kane et *al.*, 2015; van Dierdonck and Debackere, 1988). University-industry collaboration can be a significant source of revenues for universities and provides industry with important new technologies (Siegel, Waldman, Atwater, and Link, 2004). Of course, the characteristics of these technologies influence firm industrial partners' selection. Small firms are more likely to take on early-stage technologies, while large companies are more inclined to take on later-stage technologies (Thursby et *al.*, 2001). Licensing income and other revenues may be re-invested in research but also in funding graduate students, laboratory equipment, and other research tools (Lee, 2000).

University-industry collaboration might also provide entrepreneurial opportunities for faculty members and students. In this respect, new venture creation represents a further conduit for science commercialization, often when the valuable knowledge is tacit and not patentable. In this situation, creating a new venture is the only way for transferring this technology. A new venture can be also created in the presence of a patented technology invented in the university's laboratory. The license is granted to an entrepreneur who can launch a startup firm based on the transferred technology (Siegel and Phan, 2005). The university scientist could be the entrepreneur who founds the startup, or s/he could serve on the board of directors or be a technical consultant. These new ventures may also benefit from support structures such as incubators or science/research parks within or close to the university (Phan et *al.*, 2005), which may deliver several services. Overall, geographic proximity to universities allows new ventures to gain access to a skilled workforce, laboratories, and relevant expertise (Bercovitz and Feldman, 2006). Some university characteristics associated with spin-off firm formation are well established in the literature, such as intellectual eminence (Di Gregorio and Shane 2003), faculty quality (Powers and McDougall 2005), and scientific productivity (Van Looy et *al.* 2011). At the same time, it is also increasingly recognized that some university-level factors influence the founding environment (Beckman and Burton 2008; Bercovitz and Feldman 2008) and, in turn, affect the rate of academic entrepreneurship. In this perspective, technology transfer activities may help universities to become an anchor tenant in their regional context and contribute to local growth by mobilizing knowledge, talented people, and firms (Feldman, 2005). This means that university technology transfer is much more complex and multifaceted than patenting activity and new venture creation, since it includes also knowledge spillovers and teaching activities. Consequently, the role of entrepreneurial universities is broader than only generating and transferring knowledge (Audretsch, 2012), since it might provide adequate entrepreneurial environments for their students, academics, and staff to explore/exploit entrepreneurial activities (Guerrero and Urbano, 2012), according to several innovation policies in most countries (Wright et *al.* 2007).

2.2 The economic impact of university technology transfer activities

Despite high expectations and significant attention to the role of universities in shaping vibrant entrepreneurial ecosystems, the results in many contexts appear disappointing (Harrison and Leitch 2010; Siegel and Wright 2015). Consequently, several studies have addressed the question of why some universities are more effective in commercializing knowledge than others by focusing on technology transfer in general (Rasmussen et *al.* 2006), or on specific forms such as patenting (Siegel et *al.,* 2007), licensing (Shane, 2004) or spin-offs (Rasmussen and Wright, 2015; Wright et *al.,* 2007, Link and Scott, 2005), or putting emphasis on the scope and quality of knowledge and technology generated within leading and mid-range universities (Wright et *al.*, 2008). Some scholars have examined institutions that facilitate commercialization and entrepreneurship, such as TTOs (Wright et *al.*, 2007), science parks (McAdam and McAdam, 2008), and incubators (McAdam et *al.*, 2006). Other scholars have stressed the relevance of being embedded in a supportive local community (Degroof and Roberts, 2004). From a broader point of view, prior work largely recognizes the following aspects: (1) university technology transfer is multifaceted and involves many levels within the university (i.e. individual scientist, research group, department, central university, TTO, and other support infrastructure), as well as many external actors in industry and the public sector; and (2) contextual variety in terms of technological, human, and financial capital also influences whether and how universities can promote technology transfer. Therefore, identifying a number of factors associated with university technology transfer effectiveness has limited value without a better understanding of why these relationships exist. These relationships represent the theoretical basis of the evaluation models that have been applied to measure universities' economic impact (Bozerman et *al.*, 2015; Guerrero et *al.* 2015).

Traditionally, the economic impact of technology transfer has been estimated applying input-output models, which largely use IP activity measures. For example, based upon the AUTM annual surveys in the years 1996-2010, Roessner et *al*. (2013) have analyzed university licensing in the U.S. and the number of jobs created as well. Accordingly, Cardozo et *al.* (2011) found that growth in revenues was negatively correlated with TTO cost and efficiency. Also related to measuring technology transfer impact, some scholars have estimated the impact of public higher education on national and regional economies (Feldman and Desrochers, 2003; Lendel, 2010; Vogel and Keen, 2010). Input-output models have recently been replaced in favor of dynamic approaches, measuring appreciable growth in GDP and employment (Goldestein, 1990; Drucker and Goldstein, 2007; Guerrero et *al.* 2015) or more composite methodologies (i.e., productivity, total factor productivity, return on investments, quartile regression analysis) to explore the direct impact of specific research activities. Major research trends of these studies are to benchmark technology transfer performance of universities with major outputs such as licensing income, startups, and patents by using Stochastic Frontier Efficiency or Data Envelop Analysis (Anderson et al., 2007). Taken together, the evaluation of university economic impact has raised several questions ranging from the appropriate measures of technology transfer to the multi-level unit of analysis (Grimaldi et *al.*, 2011). By using count measures of science commercialization, the economic impact is disproportionately measured assuming that transferring patents or creating a startup means directly creating economic wealth. Of course, this is an oversimplification that calls for more attention. For example, university may create a strong impact on industry by training firms' personnel or providing scientific equipment and instruments. In similar vein, the Global Entrepreneurship Monitor (GEM) data has demonstrated a positive correlation between training and GDP per capita in high-income countries (Levie and Autio, 2008) and highlighted the relevance of entrepreneurship training and entrepreneurial environments of universities for economic development of the country in general.

While training and a variety of different industry collaborations are often thought of as more important outputs associated with influencing the university's economic impact, this study focuses on IP activities and new venture creation because a vast majority of scholars adopt these technology transfer count measures (see for example, Thursby et *al*., 2001; Siegel et *al.*, 2003; Anderson et *al.,* 2007; Heisey and Adelman, 2011).

This is consistent with practices in governmental agencies and universities as well, since managers often focus attention on accountability and improvement programs devoted to "managing for results." These evaluations may simply be a ranking of leading institutions and do not provide much indication about their strategic goals and the expected domain of influence of technology transfer activities (Schalock and Bonham, 2003). If evaluation models include universities' strategic initiatives, such evaluations would be much more effective since they would incorporate the universities' stated strategic objectives. For example, universities might claim their technology transfer activities have a *local impact* by boosting academic entrepreneurship or, conversely might pursue an *outreach impact*, by promoting their scientific leadership. Therefore, a common problem for most evaluation efforts is the failure to take into account strategic goals of university technology transfer. Accordingly, recent evaluation studies argue that logic models within and mapping techniques may help to introduce relations among inputs, processes, outputs, and impacts in program evaluations (Frechtling, 2007). Management studies may enrich this debate by introducing the business model concept, which emphasizes how universities orchestrate their technology transfer activities for value creation and rent capture, according to their strategic goals. This may help improve evaluation programs to harness universities in their technology transfer activities.

2.3 Defining university technology transfer business model

Over the past two decades, the term "business model" has gained prominence among academics and practitioners (Massa et al., 2017). Despite several definitions, the business model concept has emerged as a unit of analysis involving activities systems that solves the problem of value creation and value capture (Baden-Fuller and Haefliger, 2013). Interestingly, this concept has been also adopted outside the management literature, to understand the political parties such as the Labor Party in the UK (Faucher and King, 2008) and to discuss the model of the US economy (Cappelli, 2009). Despite this increasing interest in the potential of business model in several fields, university business models still represent a neglected issue, with few exceptions (Dottore et *al*., 2010; Mets 2010; Miller et *al*., 2014; Cesaroni and Piccaluga, 2015).

At the beginning, the university business model concept has been used to better examine one technology transfer option and its impact on university activities systems. For example, Dottore et *al.* (2010) have examined the spinoff process by exploring the case of the Muenster University of Applied Sciences, while Mets (2010) focused on patenting activities among five European universities from Sweden, Finland, Estonia, and the Netherlands to understand how patents affect publications and the emergence of entrepreneurial universities (cf. Bercovitz and Feldman, 2006). Later, Miller et *al.* (2014) have used the university business model concept to highlight the multiple relationships that U.K. universities have entered to promote regional innovation systems and how these internal and external stakeholders influence university business model transitions. In addition, Cesaroni and Piccaluga (2015) found the broader engagement with society by analyzing a sample of Italy-based universities. Taken together, these studies share the common theoretical idea that university technology transfer can be seen as a system of several activities that, in turn, may lead to different configurations (specific choices regarding the role of openness and the characteristics of the involved stakeholders).

However, little scholarly work has been done to identify types of university business models depending on openness. In a university, the relevance of openness is twofold: first, it refers to the open innovation approach (Chesbrough, 2003) that assumes that the intellectual property that has not yet reached the product stage may nurture the markets for technology (Arora et *al.*, 2001). Universities are a key player in these markets. Second, openness refers to the value of science as a public good and thus the recognition that technologies can be shared with several users or even competitors to support learning and establish communities with similar, professional interests (Henkel, 2006).

Most studies recognize that business models describe the rationale of how an organization creates, delivers, and captures value (economic, social, or other forms of value) in relationship with a network of exchange partners (Massa and Tucci, 2013). Part of the business model is the articulation of the value proposition, or what the stakeholders find of value in the offerings of the organization (Afuah and Tucci, 2003), in this case the university technology transfer's offering. Value creation refers to stakeholders and how they are engaged (McGrath and MacMillan, 2000), and value capture identifies how value is delivered and monetized (Teece, 2010). Accordingly, Baden-Fuller and Mangematin (2013) have specified four constitutive elements of a business model: customer sensing, customer engagement, monetization, and value chain linkages. In the university settings, these elements can be transposed by focusing on key technology transfer activities universities prioritize (value chain linkages), which internal and external stakeholders they want to address, the subsequent organizational mechanisms to engage them, and how they benefit from technology transfer activities. Thus, understanding business models and, above all, identifying types of technology transfer business models may help universities influence their contribution to society as well as provide guidance to policy evaluation programs.

3. Methodology

In view of the fact that theory and evidence on university technology transfer business models is still rather scarce, this study take an inductive approach (Eisenhardt, 1989; Yin, 2010), which may be helpful when theory is underdeveloped. In so doing, the empirical analysis combines both quantitative and qualitative data and is thus conducted in multiple stages. This approach enables further validating the findings of the quantitative analysis by detecting novel modes of operating technology transfer within universities via complementary use of qualitative information (Edmondson and McManus, 2007). The collection of incremental findings at each stage of the empirical study provides a solid basis for inductively identifying some recurring typologies of business models being adopted by universities in the technology transfer domain. The sources of data, the multi-stage empirical analysis, and its validation using qualitative information are described next.

3.1. Data and sample

To empirically investigate distinctive university technology transfer business models, this study principally relies on the 2012 AUTM database by first identifying 144 U.S. universities based on the total amount of federal funds obtained most as of 2012. Using the AUTM surveys for the years 2002-2012, this study uses secondary data of a quantitative nature on those four main outputs of their technology transfer activities conducted in the 2002-2012 period, based on the literature and business practices previously described that are considered the key results that any university-based TTO may opt to achieve singly or collectively. Such outputs are: (a) the number of patents granted; (b) the amount of licensing income (in $ millions); (c) the number of exclusive and non-exclusive licenses and (d) the number of startups established. Also retrieved from the AUTM database is information on: (e) the number of TTO staff employees; (f) the amount of federal funding; and (g) the amount of industry-related financing. Institutions that lacked data in two consecutive years were omitted, thus leading to a final sample of 60 U.S. universities (see Appendix).

To better inquire into the phenomenon of university technology transfer, the above four dimensions may be displayed dynamically or statically. One can study the inter-temporal evolution (or dynamics) of such a phenomenon by measuring the compound annual growth rate (CAGR) of the number of patents granted and startups created by each of the 60 university TTOs in the time period. Patent CAGR (rather than licensing CAGR) is calculated, as patents represent a "general purpose technology" enabling universities to engage in the promotion of both licensing agreements and startup creation. As explained above, patenting opens up the possibility for universities to develop a sort of platform business model (Rumble and Mangematin, 2015), which is suitable to engage with two distinct stakeholder groups: (a) established firms for potential licensing contracting or (b) students or academics willing to become entrepreneurs via startup creation (e.g., startups may be established to exploit a newly patented technology). Hence, patent exploitation may be direct via licensing, or indirect via the creation of startups (which, may, in turn, also decide to license out their own patents).

To provide a more balanced view of university technology transfer activities, patent and startup yearly (number) flows (*dynamic* lens) need to be complemented by a measurement of a single dimension at one point in time (*static* lens), represented by the amount of licensing income after the period of study, which quantifies the most recent revenue-generating potential of a TTO associated with the direct form of patent exploitation through the closing of own technology licensing agreements with third (private) parties. Licensing income after the study period is also a reasonable proxy for the actual size of TTOs (size effects related to startups are often unobservable due to the lack of relevant data). The natural logarithm of licensing income insures uniformity and thus ease of comparability with the rest of the variables. Analogously to what applies to enterprises whose revenues generated from core business (alternatives are total assets or numbers of employees) are conventional proxies for their sizes (the higher their revenues, the bigger the size of their operations in the market), annual revenues from licensing approximates the size of the internal TTO of specific universities relative to the rest of the sample fairly well.

The nature of university licensing business may be also investigated by computing the ratio of the number of exclusive licenses to that of non-exclusive licenses cumulatively signed with private parties (in the 2002-2012 period). A ratio significantly greater than 1 implies a dominant use (by the university TTO) of exclusivity clauses when designing licensing contracts. This means that the university TTO is placing less emphasis on openness and sharing of proprietary innovation, which is inversely correlated with the use of non-exclusive agreements. On one hand, exclusive licensing agreements are conceived as an incentive to encourage early-stage private investments in university-driven discoveries so as to translate them into new products. By granting a restricted, commercial use of the patent to only one company, universities tend to aid investing firms in taking the risk of developing an early-stage technology while also addressing the investor's need to better protect it against potential competitors. This is especially widespread in the life sciences field, whereby subsequent clinical trials require increasingly larger investment outlays. On the other hand, exclusive licensing agreements may prevent local private companies from manufacturing innovative products at affordable prices, thus affecting the social value of scientific research. This ratio is conceived as a way to synthesize literature findings on the extent of (non)openness of universities in delivering the outputs of their innovation activities to the benefit of their stakeholders.

The longitudinal database presented above is further enriched with qualitative information on the initiatives that all 60 select universities deployed to engage their stakeholders. More specifically, this study made use of additional secondary data of a qualitative nature retrieved from the annual reports available on the TTO websites and related press releases, as well as videos of university provosts' and presidents' addresses. Some annual reports provided insights into the goals and priorities of each university "third mission" enabling the collection of further elements of the adopted business models. However, most institutions' annual reports and websites failed to fully disclose the key numbers and details on the implementation of their "third mission" strategies. Thus, a further round of inquiries and repeated follow-ups via emails or skype calls with such institutions was needed so as to collect some missing data.

To obtain a more thorough overview of some university technology transfer activities, 22 semi-structured interviews with university provosts, TTO senior managers, and scientists, (all 60 university TTO staff were contacted but only 22 responded in enough detail) were conducted. Of the 22 respondents, two refer to private universities that have an emphasis on life sciences. This added more variety on data collected to explore TTO business models. Information from public universities with large TTOs with national outreach was also included. Table 1 shows some details of respondent TTOs (names are withheld for reasons of confidentiality).

Table 1 – Data on respondents universities (2012)

University	Ownership	TTO Staff	Respondents	TTO Managers	Provosts & Presidents	Scientists
Univ#1	Public	161	3	2	1	
Univ#2	Public	89	2	1		1
Univ#3	Private	46	1	1		
Univ#4	Public	20	1	1		
Univ#5	Public	33	1	1		
Univ#6	Public	13	2			2
Univ#7	Public	31	5	2	1	2
Univ#8	Public	25	2	2		
Univ#9	Private	17	1	1		
Univ#10	Public	24	2		1	1
Univ#11	Public	31	1	1		
Univ#12	Private	6	1	1		

To compensate for such a limited number of semi-structured interviews with TTOs, the first author attended two AUTM workshops held in 2013 and 2014, and had numerous informal conversations with participants. After each interview or conversation, a memo summarizing insights from such primary data so as to facilitate exploration of new avenues for theorizing about the phenomenon at hand was prepared. Informants were asked about anecdotal evidence on the historical evolution of their university technology transfer activities as well as their own motives, objectives, and roles within their respective TTOs. Informants were also required to describe the key strategic technology transfer initiatives pursued by their universities (for example, those displaying an entrepreneurial attitude).

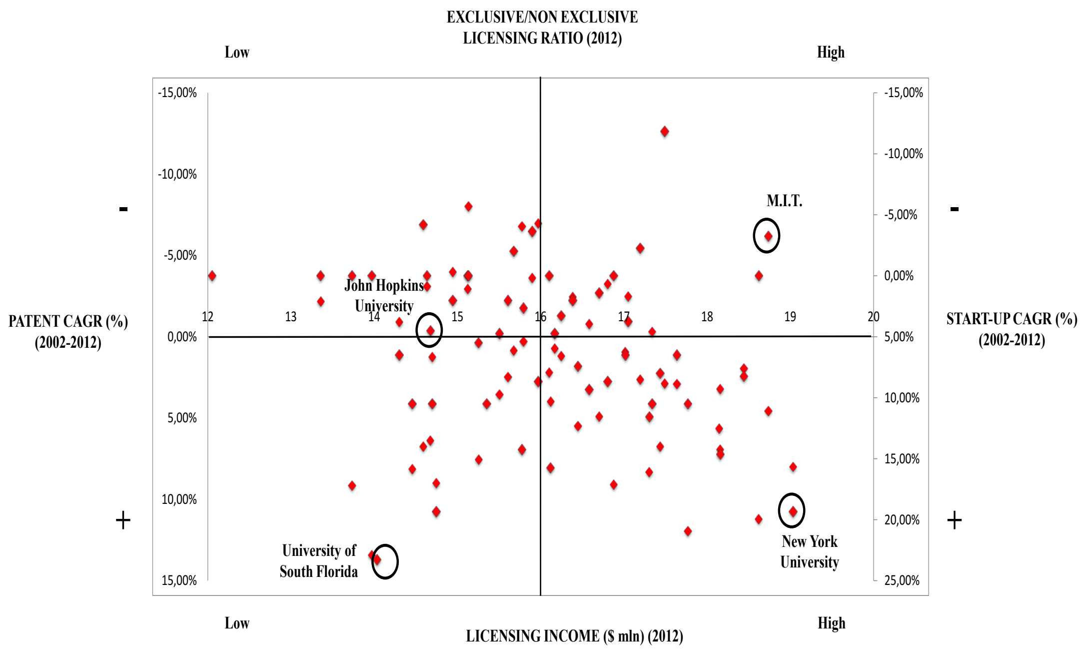
Overall, the above primary and secondary data arising from the combined use of different sources of mostly qualitative information (e.g., annual reports, websites, semi-structured interviews, informal conversations with workshop participants) were aimed at reinforcing the validation of the proposed framework for the classification of distinctive typologies of university TTO business models (cf. O'Donoghue and Punch, 2003), as discussed next.

3.2 Data analysis

The data analysis consists of three stages. First, an analysis of the AUTM data on 60 U.S. university TTOs combining both descriptive and statistical tools (stage 1). A discriminant analysis follows (stage 2). The findings of the quantitative inquiry are finally strengthened by the complementary use of qualitative information on "third mission-" related strategies of such universities obtained from the collection of documentation (e.g., annual reports, videos), interviews, and workshop participations (stage 3).

Stage 1. The best way to describe the potentially distinctive technology transfer strategies adopted by the 60 U.S. universities of the sample is the creation of a graph (scatter plot) showing how their various TTOs are scattered in a strategy space formed by the four dimensions previously identified as the important drivers (and related outputs) of any technology transfer practice (patent CAGR, startup CAGR, licensing income, exclusive/non-exclusive licensing ratio). In terms of visualization, as the key interacting dimensions are four and each pair, resulting from displaying two variables at once, represents the four most recurring (empirically observed) technology transfer practices altogether, a 2x2 matrix with four quadrants is best suited to provide a comprehensive framework of TTO strategies. It took a few iterations to find a matrix that, based on the actual AUTM data, could best display the four most frequently observed strategic modes of TTO operations across U.S. universities. The combination of four (rather than two) dimensions into a standard 2x2 matrix yields an unconventional, albeit efficient, mapping of a complex phenomenon via a synthetic and a comprehensive representation (a single, four-quadrant map). Thus, developing a strategic map enables one to empirically group all universities based upon their strategic goals on how to conceptually design and effectively conduct their TTO operations. Depending on the interactions among two out of the above four dimensions (associated with four pairs of the original variables), the 60 U.S. universities of the sample are positioned in the four quadrants of a university technology transfer strategic map (Figure 1). Each quadrant is fully characterized by a single pair of dimensions (one measured vertically and the other horizontally; for example, low licensing income and high patent CAGR), thus accommodating a potentially distinctive group of university TTOs, with the other pair of residual dimensions helping to better understand the less dominant characteristics of each TTO group.

Figure 1- University Technology Transfer Strategic Map



Source: Authors' elaborations based on AUTM data

Boundaries among the quadrants of the strategic map are simply determined by computing the median values of each of the four variables. Calibration of boundaries based on median values insures a fair and replicable allocation of scattered observations across the four quadrants of the matrix. Indeed, the median is a reference value that can be utilized for any possible sample of TTOs. The only exception is the upper boundary (related to the exclusive/non-exclusive licensing ratio), for which a median of 3 would not represent a common propensity for the non-exclusivity of licensing activities (ratio with values lower than 1). This suggested splitting the sample of university TTOs into two groups based on the mean (0.5) of such a ratio so as to separate those (fewer but present) more inclined to exclusive licensing (with a ratio greater than 0.5) from those (mostly) pursuing non-exclusive licensing.

Value ranges associated with each of the four axes are defined in excess of the actual extremes (maximum and minimum) contained in the dataset to strengthen the generalizability of the proposed framework. Value ranges and boundaries associated with each of the four quadrants of the map are summarized in Table 2.

Table 2 – University Technology Transfer Strategic Map: Value Range and Boundaries

Factors	Value Range	Boundaries
Licensing Income	\$ 0 / \$ 200 million (logarithmic transformation – range: 0 / 20)	\$ 100 million (log transformation: 16)
Startup CAGR	- 15% / + 25%	+ 5%
Patent CAGR	- 15% / + 15%	+ 0%
Exclusive/Non-Exclusive Licensing Ratio	0.0 / 6.0	0.5

The projection of four strategic technology transfer modes into four quadrants of a 2x2 matrix provides reasonable grounds for a normative classification of distinct typologies of TTOs, thus providing preliminary empirical evidence for the existence of potentially four sub-groups of universities scattered in the technology transfer business model space. However, such empirical evidence needs further validation to make the proposed framework sufficiently robust for future extended use enabling allocation of additional TTOs based on their prevailing strategic goals.

Robustness checks, conducted on the main features of the university technology transfer strategic map for a reinforced validation of the preliminary analysis, are described next. Robustness of the framework is tested by performing both correlation and variance analyses. The four selected variables forming the strategic map are weakly (or even negatively) correlated implying that the combined set of information on technology transfer operations have potential for explaining the phenomenon of emerging university TTO business models. The correlation matrix is shown in Table 3.

Table 3 – Correlation Matrix

	Licensing Income (Log)	Start-Up CAGR	Exclusive/Non-Exclusive Licensing Ratio	Patent CAGR
Licensing Income (Log)	1			
Start-Up CAGR	-0.2826	1		
Exclusive/Non-Exclusive Licensing Ratio	-0.2798	0.1949	1	
Patent CAGR	0.1237	-0.0749	0.1097	1

N = 60. All correlations are statistically significant at p<0.05 or smaller.

To further test the robustness of the proposed empirical framework suggesting a tentative classification of four distinct types of university TTO business models, a multiple one-way analysis of variance (ANOVA) was also conducted. Such findings reveal that TTO groups, scattered across the four quadrants of the strategic map based upon patent and startup growth, are significantly different, for example, with regard to licensing income. Moreover, the TTO size (based on the number of its staff employees) is a discriminant factor of distinct business models varying with the number of startups universities are able promote over time (startup growth). The key results of the variance analyses are reported in Table 4.

Table 4 – Analysis of Variance (One-Way ANOVA)

Variable	Dimension	F	Prob > F
Licensing income	Patent growth	3.75	0.016
Licensing income	Startup growth	5.07	0.004
TTO size	Startup growth	6.07	0.001

Stage 2. To strengthen the encouraging results of the above descriptive / statistical analysis, a linear (predictive) discriminant analysis is performed. The discriminant analysis has been

used both in strategy (Ramanujam *et al.*, 1986; Lewis and Thomas, 1990; Hoffmann and Schlosser, 2001) and entrepreneurship (McDougall, 1989; Moreno and Casillas, 2007) research. The aim of such an analysis is to divide a sample of units into distinctive groups and detect those minimum key factors enabling group discrimination instrumental in experimental studies and related theory formulation. More specifically, the discriminant analysis allows to perform both (a) the *characterization* (based on some key variables) and (b) *classification* of a sample of observations by utilizing a subset of units, whose group membership is known (training phase), to estimate those coefficients that are needed to classify newly added units (analysis phase).

Assuming a normal distribution and weak (cross-) correlation of predictive factors, a number of discriminant functions (equal to the number of groups minus one) is created so as to estimate a threshold value that discriminates among groups. All values generated by the discriminant function(s) have mean equal to zero, variance equal to one, and ensure the highest possible difference among group means. The outcome is a classification system where, once all distinctive groups have been characterized, any new unit can be assigned to one of the groups based on its own characteristics.

3.3 Results of the discriminant analysis

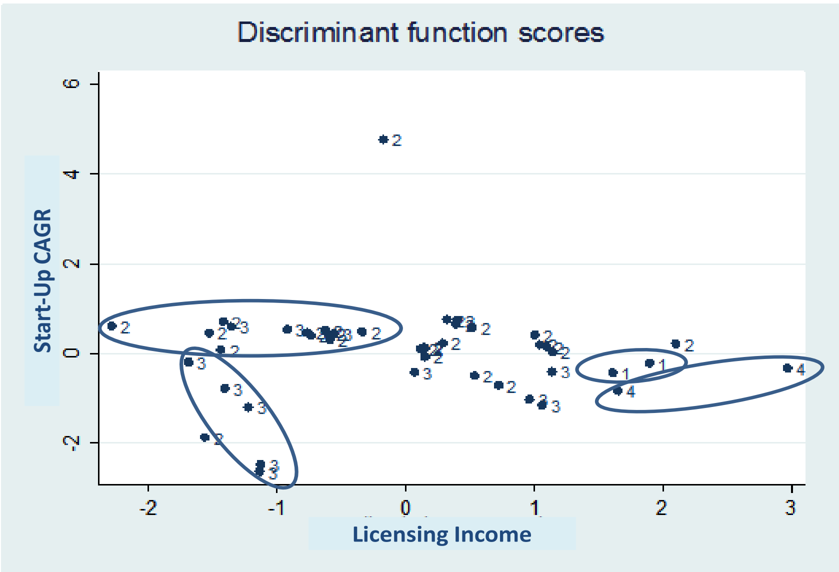
We performed a discriminant analysis on the technology transfer activities of the select university sample using their four characteristic dimensions (patent CAGR, startup CAGR, licensing income, and ratio of exclusive to non-exclusive licenses). Such analysis yields the so-called "canonical structure", that is a set of discriminant factor loadings measuring correlations between observed variables and unobserved discriminant dimensions. An example of discriminant functions (including factor loadings) produced by the analysis is the following:

discriminant score = 1.04*licensing income + 0.65*startup growth – 0.079*exclusive/non-exclusive licensing – 0.037*patent growth

where loadings associated with licensing income and startup growth influence, more than others, the attribution of a discriminant score to observed units of the sample. The highest loading is that of the licensing income factor, thus best discriminating among emerging university technology transfer business models. Startup growth also significantly helps differentiate the way universities may choose to conceptualize and execute their technology transfer activities. The ratio of exclusive to non-exclusive licensing and patent growth are instead much less important in identifying typologies of university technology transfer business models. It should be noted that discriminant function loadings operate similarly to OLS regression coefficients. For example, one standard deviation increase in the licensing income variable will result in a 104% standard deviation increase in the predicted values of the discriminant function.

Based on the scores obtained by solving the discriminant functions, university TTOs may also be plotted into a space formed by the principal discriminant dimensions (licensing income and startup growth), thus leading to a "score plot" (Figure 2). Sub-groups previously identified in the strategic map are assigned an ordinal (identification) number from one to four. The score plot clearly shows that the key dimensions of licensing income and startup growth enable the formation of four university technology transfer strategic groups opting for distinct business models (circled in Figure 2).

Figure 2 – Discriminant Function Score Plot for University Technology Transfer



3.4 Validation using qualitative information

Stage 3. Finally, the findings from the prior quantitative analysis are further validated by coding all information of a qualitative nature obtained from interview transcripts and memos, annual reports, and all archival documents (e.g., videos) concerning the strategic goals each university in the sample intends to achieve via its own technology transfer activities, as well as the most interesting and novel initiatives launched to promote stakeholders' engagement. More specifically, a multi-coding process of the data has been performed using the NVivo software and considers the business model elements as an orienting framework for interpretation (Kelle, 2007; Aversa *et al*., 2015). Data have been arranged into two high-level categories: "strategic goals" (e.g., announced/described by the reference president, provosts, council) and "strategic initiatives for technology transfer" (e.g., announced/described by the reference president, provosts, deans and department chairs, TTO directors). Data on "strategic initiatives" have been further reorganized based on the extent to which they have "local impact" or "outreach impact." Data on "strategic goals" have been regrouped according to the related stakeholders' focus into two subcategories: "internal stakeholders" and "external stakeholders." Table 5 provides some quotations about strategic initiatives grouped according to their local or outreach impact.

Table 5 – Examples of illustrative quotes on strategic initiatives for technology transfer

Key initiatives with local impact	*"the real benefit of our work is our ability to arrange several meetings and workshops where people can meet and talk with venture capitalists"* (Dean, Business School)
	"As provost, I hope my university can be ranking among the top. Having an incubator may attract students … This also helps getting federal funding." (Provost)
	"Metrics are something wrong. The TTO does not create startups, but only equal conditions for people who believe in their aspirations. Why I am going to be evaluated on numbers? That's the department performance and not mine" (TTO manager)
	"I am scientist and not headhunting …I hate to be involved in these events that waste time for my research" (Scientist)
	"I am so proud of my award! Being the inventor of the year gives me the right motivation to enter into the market. It's a great way to keep a foot in those doors" (Academic entrepreneur)
Key initiatives with	*"The future is delivering MOOCs…that can shape the future of several*

outreach impact	*students in poor countries. Other stuff is only symbolic activities to attract public money"* (President)	
	"We have to struggle with big pharma that want to sign a non-exclusive agreement, but how can I permit this? Hard to manage..." (TTO manager)	
	"Technology transfer is something that will come consequentially …The problem is good research. So our mission is doing good research. Otherwise, what are you going to transfer?" (Provost)	
	"The role of TTO is attracting money for research, for labs...startups should be supported by private firms, not by universities" (TTO manager)	

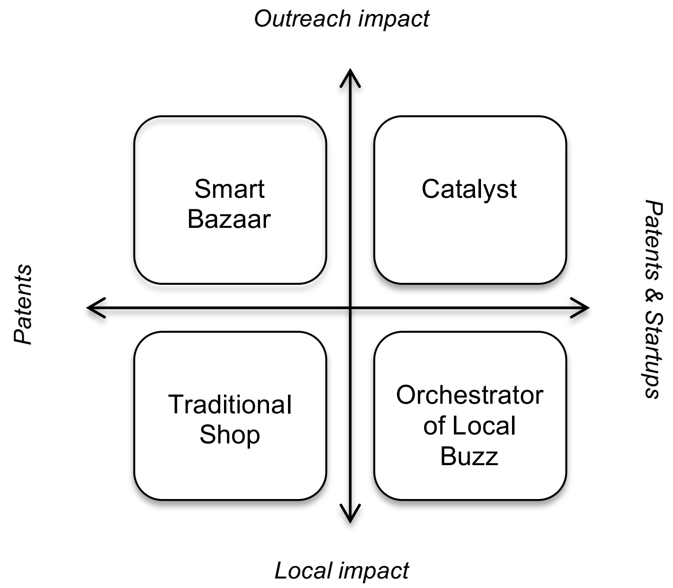
Source: interview transcripts.

At this stage, multi-coded (qualitative) information was utilized to speculate about the main components of some distinctive strategic groups of university TTOs by inductively connecting categorized quotations on strategic goals and initiatives with emerging technology transfer practices and make prior empirical evidence more robust. This further data processing validated the proposed group discrimination suggesting that there exist four emerging business models being adopted by universities for the conceptualization and implementation of their own technology transfer activities. Starting from the most recent theoretical developments on universities' "third mission," the multi-staged analysis of empirical, archival and primary data allows advancing a conceptual framework for classifying business models experimented on by universities to strategize about technology transfer (Eisenhardt and Graebner, 2007; Yin, 2010).

4. A conceptual framework for classifying university technology transfer business models

Drawing upon the empirical evidence presented above, the proposed framework identifies four distinctive university technology transfer business models that are being adopted by U.S. institutions (Figure 4). Following the logic of group discrimination (four key discriminant factors) complemented by the multi-coded qualitative information on strategic goals and initiatives, one could imagine four modes of conducting technology transfer at the university level: catalyst (mode 1), smart bazaar (mode 2), traditional shop (mode 3), orchestrator of local buzz (mode 4). These modes embody distinct business models.

Figure 4 – A typology of university technology transfer business models



Mode 1: Technology Transfer as Catalyst

This type refers to a handful of universities that emerged as catalyst and global players in the university-industry collaboration to develop disruptive innovations. According to this view, the most successful technology transfer offices were those that pushed for the highest payment and made the most money on deals. TTOs of universities acting as catalyst do not tend to maximize the number of patents obtained or the number of startups created per year, but the income from exploitation (for example, via licensing) of their disruptive innovations generated by the internal scientific community. Most of the inventions generating over $100,000 were at least ten years old, with the basic DNA cloning patents generating $37 million. These universities with strong patent policies generally also have royalty sharing policies to provide incentives to researchers to participate in technology transfer. For example, at Stanford, for each invention, 15 percent of the gross royalty income is deducted for administrative expenses. After any direct expenses (typically patent costs) are deducted, net royalties are divided one-third to the inventor(s), one-third to the department, and one-third to the school (see http://otl.stanford.edu/inventors/inventors_policies.html, viewed 01 April 2018). Other universities have a 50-50 sharing, or a sharing whose percentage changes, depending on the royalty income level. These universities are also more likely to grant exclusive licenses since exclusivity is needed to encourage firms' investment and development. Some of these technologies that have been commercialized from Stanford include the FM Music Synthesizer licensed to Yamaha, Fluorescent Activated Cell Sorter licensed to Becton Dickinson, the Acoustic Microscope licensed to Olympus, and Computer-Aided Tomography technologies licensed to General Electric.

From another perspective, universities that are catalysts are able to promote entrepreneurship as well, especially to develop early-stage inventions. Accordingly, these new ventures are more likely to grow early and globally. Taken together, technology transfer in university catalysts deeply depends on cutting edge research and is associated with high-quality education. For example, the Director of the MIT Technology Licensing Office declares that their activities "support faculty and students alike in the work to amplify MIT's global impact through the transfer of innovation from the lab to the marketplace" (https://tlo.mit.edu/engage-tlo/annual-update-letter-director, viewed 01 April 2018). Of course, this planned "search for quality" requires being selective in identifying their internal and external stakeholders, as well as large investments to provide labs and facilities supporting the international competition. Therefore, its economic impact cannot be focused only on the traditional count measures but also requires a broader view to account for their catalyst role (for example, the number of external firms co-located, the number of scientists and students enrolled, and the number of innovations in the market).

Mode 2: Technology transfer as smart bazaar

Mode 2 refers to universities that intend to generate and openly disseminate science at large, since they perceive their responsibility to respond to human needs, with particular emphasis on those of underserved populations, and in general to engage society in knowledge production and dissemination. The premise of the difference between this Mode and the prior one is twofold. First, it is worth noting that upstream patents may fail to spur innovation due to the emergence of anti-commons. Heller and Eisenberg (1998) point out that privatizing basic research may prevent further development and that this is socially inefficient, especially with regard to medicine and biotechnology. Second, most universities have chosen to exploit digital technologies toward moving all their activities—teaching, research and technology transfer—to a wider range of stakeholders, including citizens. Accordingly, they exhibit an increased awareness of the relevance of engaging faculty participation more deeply in providing online educational courses (such as MOOCs), disclosing inventions and making licensing agreements more flexible in terms of deal structures, by preferring non-exclusive terms rather than exclusive ones.

In this regard, the Johns Hopkins University is a case in point. During the last years, Johns Hopkins has promoted disclosure among faculty and non-exclusive licensing agreements as well. As reported by the Daily Record (Baltimore, MD), the vice provost for research declared "*It is a change of inflection or a change of strategy or whatever you want to call it. But the question is: What is your principal goal? The goal is to get technology out and get it used*." Taken together, these findings reveal that universities oriented toward this business model may be moving away from financial interests and revenue generation (licensing income) and lay the foundation for a more open-source model of technology transfer, which puts more emphasis on the indirect effect and informal activities rather than formal outputs (number of patents or startups). In this view, the TTO is seen as a "smart bazaar" that "crowdsources" university discoveries (cf. Afuah & Tucci, 2012), makes them accessible to society, and incentivizes education and research over revenue generation. In addition, Big Data and crowdfunding (cf. Butticè et al., 2018) help the emergence of an alternative technology transfer business model based on the principles that would alleviate the need to measure revenue-based performance. In line with this shift, many influential U.S. universities have launched online crowdfunding platforms aimed at providing critical fundraising support for innovative projects by faculty and student organizations. One of the first U.S. universities that implemented this online platform was the University of Virginia that used philanthropic crowdfunding to advance university research. "*It's our hope that this innovative initiative will build on the success of the University's proof-of-concept research programs and establish a new model for funding promising, early-stage research. Through this crowdfunding initiative, we're creating opportunities for members of the community to be a part of advancing these exciting discoveries*" said W. Mark Crowell, executive director of UVa Innovation (see https://news.virginia.edu/content/new-crowdfunding-site-allows-public-advance-uva-research-projects-through-targeted-donations, viewed 01 April 2018).

Open data are also influencing science, with particular emphasis on the biotechnology area. Providing free access to materials and databases that are intermediate scientific outcomes, open data promote a larger involvement of the global scientific community and enhance creativity and problem solving. This poses some challenging questions regarding university-industry collaboration and new practices of revealing are emerging (Henkel 2006). In a similar vein, current evaluation studies have highlighted the idea to move beyond the assessment of economic impact in science and technology policies while there is a need for greater infusion of public values (Karlan and Valdivia, 2011).

Mode 3: Technology Transfer as Traditional Shop

In mode 3, universities conceive technology transfer as a process to drive research outputs that already exist into the marketplace through patents. This is consistent with the private view that the Bayh-Dole Act brought up and, therefore, universities oriented toward this mode are more likely to promote patenting and, in general, an intellectual property rights culture indistinctively among all departments, without any targeted stakeholders. Interestingly, they strive to enlarge university patent portfolios because, as mentioned above, patents represent a "general purpose technology" that can be used both for licensing and startup creation. In a dynamic view, this represents the first step of a transition to become entrepreneurial. Consistent with prior research (Rumble and Mangematin, 2015), this represents a platform business model that may provide relatively low direct economic benefit to the university itself, even if indirectly the university and / or local region may benefit. The key technology transfer activities are mainly devoted internally to solve a possible mismatch emerging from scientists' motivation to disseminate their research and organizational tactics enabling patenting (e.g., sanitizing data for publication, postponing publications). Universities that exhibit this business model usually demonstrate lower licensing income and this suggests that technology transfer may be seen as a cost center, although there could be other explanations as well. An illustrative example is the University of South Florida. The Technology Transfer Office was established in 1990 to facilitate the commercialization of university intellectual property, including patents and copyrights. Accordingly, in 2012, the University of South Florida ranked ninth in terms of U.S. patents issued (98) within the top 10 Universities worldwide, confirming their efforts, but registered low revenue income, demonstrating that their activities are mainly focused on building patents portfolio, rather than licensing.

Mode 4: Technology Transfer as Orchestrator of Local Buzz

Mode 4 refers to universities that act entrepreneurially in order to accomplish the "third mission" (Etzkowitz and Leydesdorff, 2000), in addition to teaching and research. Entrepreneurial universities (Bercovitz and Feldman, 2006) recognize the relevance of exploiting new scientific and technological opportunities to boost local economic development. Accordingly, they enlarge their business network, to set up new entrepreneurship courses in scientific and technological departments, to arrange local business plan competitions, and to nurture an entrepreneurial culture in the local environments. In less supportive contexts, universities may act more proactively to provide facilities (e.g., incubators, contamination labs, accelerators) and engage more stakeholders. A case in point is

New York University since it devoted from its inception an increasing attention to both licensing income and academic entrepreneurship. In 2012, almost 60% of NYU patents have been licensed to companies for development and commercialization (mostly on an exclusive basis). Over the past five years, NYU has ranked first among the surveyed U.S. universities in income from technology licensing, and actively promoted entrepreneurship with the establishment of more than 70 startup companies (+87%). More generally, universities adopting this business model put their emphasis on exceptional principal investigators who might create spinoffs and attract federal funds as well. Startups and spinoffs are also in the agenda of several national and regional agencies. Therefore, universities may take advantage of this business model to gain access to public funds. Accordingly, they are suitable to be evaluated for their local economic impact, which should also include their teaching activities and their services in terms of facilities and research labs (Guerrero et *al.* 2015). Table 6 summarizes the key components of the four types of university technology transfer business models identified.

Table 6 - Comparison of University Technology Transfer Business Models

	Traditional Shop	**Orchestrator of Local Buzz**	**Catalyst**	**Smart Bazaar**
University strategic goals	Gain access to research in the marketplace	Promote entrepreneurship	Scientific leadership in disruptive innovation	Openly disseminating innovation
Key technology transfer activity	Patenting	Startup creation Spinoffs	Triple Helix research partnerships Exclusive licensing agreements	Non-exclusive licensing agreements Crowd science

Key Stakeholders	Academic scientists	Potential entrepreneurs Academic scientists Students Financial professional firms	Exceptional Principal Investigators Large corporations Govern. Agencies NGOs	Academics scientists Citizens Firms Governments
Stakeholders engagement	Tailored service Promoting IP among faculty	Awards to academic entrepreneurs Student startup competitions	Cutting-edge research labs International visibility	Standard deals for non-exclusive agreement Crowdfunding and massive open online courses.
Monetization	University support economically patenting activities	National agencies support economically entrepreneurial activities	International agencies support financially research projects Royalty sharing	Licensees pay royalties University invests in digital innovation to shape teaching and research funding
Economic Impact	None	Local impact	Outreach impact	Not pertinent Focus on public value criterion

5. Discussion, implications, and conclusions

Universities represent an interesting empirical setting for not only university managers themselves, but also industry and policymakers as well. By leveraging emergent or planned organizational processes, universities try to find a contingent fit between multiple stakeholders while influencing their span of control over economic impact. Business models that emphasize high-quality research (i.e., catalyst) and startup creation (i.e., orchestrator of local buzz) are associated with higher economic performance. In addition, these types of business models generate knowledge complementarities with teaching and research, thus shaping the university business model configuration, which includes also those referring to teaching and research (cf. Massa et *al.*, 2017)).

According to prior work (Miller et al. 2014; Cesaroni and Piccaluga, 2015), the business models lens is useful to have a systemic view of technology transfer activities and, indirectly, sheds light on the strategic role universities want to play to have a positive impact on society. Extending Miller et al (2014), who conceived business model innovation as a result of the negotiation process among multiple stakeholders, this study stresses the relevance of the strategic choice of the university, able to orchestrate its internal and external partners. One can also detect the increased role of societal and non-economic outcomes in the "smart bazaar" mode, consistent with Cesaroni and Piccaluga (2015). This study also provides further empirical findings based on the U.S. context, which has experienced much science commercialization activity.

Implications for theory

These findings have important implications for at least three research streams and provide new research avenues. First, by addressing recent concerns regarding the lack of a systematic approach in the business model literature (Massa et *al.*, 2017), this study proposes four types of business models in the university setting. In so doing, it contributes to this emergent literature (Dottore et *al.,* 2010; Mets, 2010; Miller et *al*., 2014; Cesaroni and Piccaluga, 2015) by focusing on technology transfer activities and highlighting linkages and relationships with the other two value propositions (teaching and research). Although these linkages were not directly addressed, the analysis of university technology transfer business models elucidated the role of business model configurations. In this respect, this study complements prior research (Aversa et *al.,* 2015; Zott et *al.* 2011) and confirms that technology transfer may generate economic and non-economic linkages that need to be evaluated. Therefore, the choice of technology transfer business model might be examined within the configuration of other business models that the university may implement. For example, one can speculate that universities might want to link business models focusing on developing and commercializing patents with educational programs aimed at identifying and training highly skilled scientists.

Implications for practice

By detecting four types of technology transfer business models, this study enriches prior work on university business models (Dottore et *al.*, 2010; Mets, 2010; Miller et *al.*, 2014; Cesaroni and Piccaluga, 2015) and complements empirical findings by analyzing a sample of U.S. universities' TTOs. Accordingly, future research could examine how each type of business model may evolve over time and enact business model innovation (Massa and Tucci, 2013). From a stakeholder perspective, the findings suggest that different types of university business models might be associated with distinctive governance mechanisms, which may also elude the role of TTOs as broker or boundary spanner (Siegel and Wright, 2015). For example, the catalyst and local buzz orchestrator business models suggest that (few) universities engage and reward star scientists for tech transfer activities since they already influence the achievement of university strategic goals. In similar vein, recent work on multiple roles of Principal Investigators (Cunningham et *al.*, 2015), academic entrepreneurs (Baglieri and Lorenzoni, 2014), and, more generally, academic scientists, show that top scientists may commercialize their inventions outside the formal university channels such as TTOs (Perkmann et *al.*, 2015). Taken together, they point out that technology transfer is a multi-level phenomenon, at the individual, department, and institution levels, and the university business model lens might influence organizational practices to also account for independent scientists' activities beyond the formal TTO activities (e.g., as consultant). From a TTO perspective, this confirms the timely concern to reinforce their identity and shape their legitimacy (O'Kane et *al.,* 2015).

Some scholars have recently argued that an entrepreneurial mode "is typically an overlay on a research university, but it can also be a strategy for development from a teaching university, with the phases accomplished simultaneously or even in reverse order to the usual progression" (Etzkowitz and Dzisah, 2015, p.10). In line with this reasoning, the typology of technology transfer business models proposed herein is particularly valuable to central university managers who are determined to promote a change towards their impact on society and may help their strategizing. Despite the general enthusiasm toward the third mission, it is important that university managers become aware of the intrinsic costs of technology transfer and able to exploit complementarities within education and research to counterbalance these costs. Some central university administrators are justifiably concerned to develop their visibility and scientific leadership, rather than revenues or jobs. This explains why TTOs are sometimes conceived of as a service center or, sometimes, a cost center.

For potential industry partners who are interested in absorbing knowledge spillovers, the results suggest that despite the common bias in trying to engage with the few, exceptional catalyst universities, partnering with orchestrator universities, more focused on local context, might represent a valuable way to nurture innovation. They can also negotiate distinctive deals, by providing internships or jobs opportunities for students, rather than funding for research projects. Thus, future research should more systematically examine the university-industry collaboration by taking the business model lens and explore how industry may leverage these different types of complementarities in practice.

Implications for policy

Our findings may enhance evaluation studies as well. In contrast to received wisdom, this study reveals that universities are shifting toward their entrepreneurial mission in several ways, navigating among several policies, legislative frameworks and constraints, including also embedding in poor and less supportive contexts. In so doing, they try to leverage complementarities among the three university missions and conceive technology transfer as *transversal* and *inclusive*.

In contrast, most of the evaluation studies in technology transfer settings exhibit two main drawbacks: (1) they adopt a narrow approach, taking into account only formal relationships (i.e. patenting and licensing, new venture creation), with no account for the abovementioned complementarities and (2) use count measures to measure technology transfer outputs, consistent with the "out-of-the-door" criterion (Bozerman et *al.*, 2015). By using the same measures, the findings reveal that *one size does not fit all*, and propose four types of technology transfer business models.

The analysis shows that only universities that adopt the orchestrator business model may be eligible to be evaluated following the economic approach while the other typologies may not typically be associated with these criteria. In more detail, one sees that: (a) the traditional shop business model does not create much direct economic impact since they accrue low licensing income; (b) the catalyst business model focuses on scientific leadership in the international arena, thus the economic impact may be analyzed accordingly, by using further measures (i.e., spinoff revenues, the number of external firms located in proximity to the university, talent mobility, financial resources from venture capitalists, and so on); and (c) the smart bazaar business model mainly addresses the value of science as a public good, largely neglected in evaluation programs. Consequently, smart bazaar universities often put in action initiatives that never will be included in this accountability. For example, how to account for the free sharing of research within a collaborative platform among universities, industry, and government agencies?

The smart bazaar business model creates and captures value (not economic) by widening the range of multiple stakeholders to be involved, including even citizens. In this respect, the findings of this article are consistent with recent criticism regarding the common tendency to underestimate the public value of science in assessing policy programs associated with universities and federal agencies (Sorenson and Chambers, 2008) and provide “food for thought” regarding how universities really compete in their scientific systems.

Therefore, policymakers may benefit from this study since it provides some preliminary evidence that entrepreneurial universities interact with industry and governmental agencies in different ways, according to their technology transfer business models. Consequently, evaluation programs should put different emphases in further metrics and adapt criteria and indicators. A pathway for future applications is to incorporate business model typologies as guidelines to help them to design customized evaluation reports for university technology transfer. Accordingly, future research should investigate how distinctive technology transfer business models may be associated with different evaluation frameworks.

Conclusions

This article inductively explored university technology transfer by adopting a business models lens and, accordingly, identified four types of technology transfer business models by analyzing quantitative and qualitative data collected in a longitudinal dataset of 60 US universities during the period 2002-2012. By analyzing differences in technology transfer outputs, using the same metrics largely adopted, and the consequent strategic initiatives universities have undertaken, four distinctive business models were identified. Although the contribution is preliminary, this first attempt may enrich the conversation on business models, especially in public organization settings.

This research has some limitations. Although the perspective of the university in general was the primary target of this project, the related findings may benefit from the perspective of TTO managers on this same topic. Specifically, it would be interesting to find out how in practice these business models work and how misalignments between TTOs and multiple stakeholders are solved. In a similar vein, this study could be enhanced by a faculty perspective. For example, an analysis of incentive structure systems might be beneficial to assess why some faculty members circumvent the technology transfer office and patent outside the university (Lawson, 2013). Furthermore, the findings are based on US university system that might not represent other national systems. Since US technology transfer mechanisms have played a role model, this would be a first step towards rethinking university business models' sustainability in other university systems elsewhere. Furthermore, analyzing how technology and innovation policies affect university business model innovation, especially in emerging countries, provides several research avenues for future work.

In conclusion, universities have been asked to do more and more for society over the last several decades. In addition to performing research and disseminating knowledge via teaching and publishing, they are often being asked how much they are contributing to economic growth and entrepreneurial activity. In their (and policymakers') desire to measure universities' success, the focus has been often narrowly focused on a small number of indicators, even if the universities themselves originally had different goals. Based on the results of this study, it may not be desirable—or even feasible—to use a "one size fits all" model for evaluating the entrepreneurial university of the future!

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Appendix – List of sampled U.S. universities

1 Massachusetts Inst. of Technology (MIT)
2 Univ. of California System
3 Albert Einstein College of Med/Yeshiva Univ.
4 Baylor College of Medicine
5 California Institute of Technology
6 Carnegie Mellon University
7 Case Western Reserve University
8 Duke University
9 Emory University
10 Harvard University
11 Indiana University
12 Johns Hopkins University
13 North Carolina State University
14 Oregon State University
15 Penn State University
16 Princeton University
17 Purdue Research Foundation
18 Rutgers The State University of New Jersey
19 The Research Foundation for The State University of New York
20 Texas A&M University System
21 Univ. of Arizona
22 Univ. of Chicago (UCTech)
23 Univ. of Florida
24 Univ. of Hawaii
25 Univ. of Iowa Research Fdn.
26 Univ. of Kansas
27 Univ. of Kentucky Research Fdn.
28 Univ. of Michigan
29 Univ. of Minnesota
30 Univ. of Missouri System
31 Univ. of North Carolina/Chapel Hill
32 Univ. of PA
33 Univ. of Rochester
34 Univ. of Tennessee
35 Univ. of Virginia
36 Univ. of Washington/Wash. Res. Fndtn.
37 Vanderbilt University
38 Virginia Tech
39 Washington State University
40 Univ. of Nebraska
41 UW-Madison/WARF
42 Washington University of St. Louis
43 University System of Maryland
44 University of Texas System
45 Arizona State University
46 Mount Sinai School of Medicine of NYU
47 Georgia Institute of Technology
48 Michigan State University
49 Ohio State University
50 Stanford University
51 Univ. of Colorado
52 Univ. of Illinois/Chicago & Urbana Ch.
53 Univ. of Massachusetts
54 Univ. of Miami
55 Univ. of New Mexico/Sci. & Tech. Corp.
56 Univ. of Pittsburgh
57 Univ. of South Florida
58 Univ. of Utah
59 New York University
60 Northwestern University