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ACADEMIC ENTREPRENEURSHIP: THE UNIVERSITY TECHNOLOGY TRANSFER OFFICE

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ESPOSIZIONE RIASSUNTIVA DEL LAVORO SVOLTO –

SUMMARY OF THE THESIS

Il primo capitolo analizza il tema del trasferimento tecnologico attraverso la prospettiva della teoria istituzionale. Lo scopo dell'elaborato è di delineare gli elementi istituzionali formali e informali che sono cambiati nel paradigma dell'imprenditorialità accademica nel contesto americano ed europeo attraverso un'analisi della letteratura. In particolare viene usata la specificazione di Aoki, che unisce la teoria istituzionale e la teoria dei giochi, e consente di definire il contesto istituzionale come il dominio di scambio politico con complementarità istituzionali dinamiche.

Seguendo la categorizzazione di istituzioni formali e informali fornita da North, e basata sui tre pilastri delle istituzioni definite da Scott (regolativo, normativo e culturale-cognitivo), l'elaborato prosegue raccogliendo i contributi teorici della letteratura sul tema dell'imprenditorialità accademica.

Il contributo teorico si compone principalmente di due aspetti: da una parte una nuova configurazione istituzionale dell'imprenditorialità accademica utilizzando le definizioni teoriche proposte da Aoki, dall'altra una categorizzazione della letteratura per gli impatti forniti dalle varie istituzioni formali ed informali al trasferimento tecnologico universitario suggerendo che il processo di cambiamento istituzionale possa non avere un ordine gerarchico in termini di casualità ma necessiti soprattutto di coordinamento.

Il secondo capitolo analizza le relazioni tra i principali stakeholders coinvolti nel processo di creazione di uno spinoff accademico, proponendo una lettura innovativa del problema del funding gap ampiamente descritto dalla letteratura quando parla di nuove aziende innovative, scientifiche o tecnologiche.

Analizzando il database degli spinoffs fondati dall'University of Michigan attraverso metodologie statistiche sofisticate e controllando per fattori importanti come le caratteristiche del brevetto dato in licenza, le caratteristiche del capitale umano e le risorse fornite dai network professionali, lo studio scopre una relazione molto stretta tra i fondi di commercializzazione forniti dall'ufficio di trasferimento tecnologico e la probabilità di ricevere poi finanziamenti privati da venture capitalists.

La spiegazione fornita per spiegare questo fenomeno viene dalla teoria dei giochi, dove in caso di asimmetrie informative (Akerlof, 1970) l'uso di segnali aiuta nel differenziare le

migliori aziende da tutte le altre presenti nel mercato. In particolare, il segnale fornito dai sussidi pubblici alle nuove aziende innovative era stato studiato in maniera teorica da Chan (1983), Lerner (1999), e Takalo e Tanayama (2010).

I contributi innovativi della ricerca quindi sono prevalentemente due: (i) un primo studio empirico degli effetti dei fondi di commercializzazione forniti dall'ufficio di trasferimento tecnologico, nel contesto di uno stato federale nella media e quindi al di fuori degli ecosistemi altamente specializzati e difficilmente comparabili della Silicon Valley (Stanford University) e della Route 128 (MIT); (ii) un'interpretazione molto interessante del fenomeno e delle relazioni tra l'ufficio di trasferimento tecnologico e la comunità degli investitori privati venture capital, dimostratasi in diversi studi essenziale per la sopravvivenza, lo sviluppo e la crescita delle nuove aziende tecnologiche, sia per le loro capacità di finanziamento che per le loro attività di supporto e coach.

Il terzo capitolo si pone come un'estensione del secondo, dove la domanda di ricerca è se i fondi di commercializzazione forniti dall'ufficio di trasferimento tecnologico abbiano anche un effetto sulle performance a lungo termine degli spinoffs analizzati in precedenza.

Per fare ciò, al database precedente vengono aggiunte le informazioni relative alle vendite degli spinoffs, e in particolare la crescita assoluta nel triennio 2007-2010.

I metodi applicati sono analisi descrittive e analisi della distribuzione, oltre alle analisi quantitative regressive.

Le analisi delle distribuzioni dei gruppi di spinoffs che non hanno ricevuto nessun supporto economico, che hanno ricevuto solo i fondi di commercializzazione e che hanno ricevuto entrambi i finanziamenti evidenzia che questi tre gruppi sono completamente diversi tra loro (Wilcoxon-Mann-Whitney test), evidenziando quindi che sia i fondi di commercializzazione che i fondi di venture capital hanno un effetto determinante nella crescita degli spinoffs.

Le regressioni a loro volta mostrano il comportamento tipico evidenziato da Baron e Kenny in caso di variabile mediatrice.

Vengono quindi ulteriormente rinforzati i risultati del secondo capitolo, mentre solo le analisi delle distribuzioni permettono di affermare un impatto positivo dei fondi di commercializzazione sulla crescita degli spinoffs indipendentemente dalla presenza di venture capital, perché nelle analisi regressive impatto delle aziende finanziate da venture capital oscura invece i modesti risultati di quelle finanziate solamente dai fondi di commercializzazione.

The first chapter analyzes the subject of the technology transfer process with the perspective of the institutional theory. The scope of the paper is to delineate the formal and informal institutional elements that changed in the academic entrepreneurship paradigm through a review of the literature. In particular, I use the Aoki's theoretical point of view that unifies institutional theory and game theory, and defines the institutional context as the political exchange domain with dynamic institutional complementarities.

The emergence of the university entrepreneurship paradigm has been an incremental change, recalling the theoretical idea that institutional evolution involves transitions among three aspects of institutions, which Scott (1995) called pillars: the regulative, normative, and cognitive, together shaping the creation of a new common approach. One aspect may be dominant at any given time, but the three coexist and are interconnected (Hirsch, 1997).

The scope of this paper is to delineate a picture of the institutional elements that changed in the academic entrepreneurship field through an analysis of the literature contributions of the formal and informal institutions acting in the technology transfer process, applying the theory on institutional change developed by Aoki (2001).

Formal and informal institutions in the university technology transfer process, in a unified perspective, suggest that the process of institutional change may not necessarily be hierarchically ordered in terms of causation, but it needs a coordination between the different institutions and domains.

The second chapter analyzes the relations between the main stakeholders involved in the transfer process of scientific knowledge to society, proposing an innovative perspective on the funding gap problem, widely described in the literature regarding technological and scientific new ventures.

The aim of this study is to appraise the influence of the commercialization funds provided through the university TTO on the probability to receive venture capital follow-on funding through the database of all the spinoffs created to exploit University of Michigan-assigned inventions from 1999 to 2010 and controlling for other important drivers of VC investments' decisions, i.e. the spinoff's technological endowment, the founders' human capital and network's resources.

In line with theoretical contributions proposing a signaling role of public funding in reducing the information asymmetry faced by private investors (Chan, 1983; Takalo & Tanayama, 2010; Lerner, 1999) and suggesting a further enriched role for TTOs, the findings point out

that venture capitalists perceive the gap funds as a signal about the quality and credibility of the new businesses, and use the information to identify the best spinoffs to finance.

The contribution to the literature are mainly two, with important policy implications in the academic entrepreneurship environment: (i) a study of the effects of the TTO gap funding support, a practice that has become widespread in the universities' policies, but received little attention in the academic researches; (ii) a new interpretation of the relations between scientists, technology transfer offices and venture capitalists, the main stakeholders involved in the transfer process of scientific knowledge to society.

The third chapter is an extension of the second one, investigating if the provision of TTO gap funding to spinoff companies at the embryonic phase has an influence in their consequent sales growth and an impact on spinoffs development. With this scope, I analyze how the funding support provided through the University of Michigan's technology transfer office influences spinoffs' sales growth.

To the U-M Tech Transfer's database, are added the information regarding the spinoff's sales through the Orbis database, in particular the absolute growth in the period 2007-2010. The methods used are descriptive, distributional and quantitative analysis.

The analysis of the distribution of the spinoffs that receive (i) no economic support, (ii) only the university commercialization funds and (iii) both TTO gap funds and venture capital evidences a clear difference between the three groups of spinoffs, supporting the hypothesis of a moderate impact of TTO gap fund, and a high influence on sales growth of venture capital investments. We test the distributions equivalence and reject the null hypothesis of the equality of the distributions with the Wilcoxon-Mann-Whitney test.

The regressions provide support also to the analysis of the second chapter, sustaining the presence of a mediating variable through the Baron and Kenney's test.

The results show that the sales growth was not uniform, and superior performances couldn't be justified only by the provision of TTO gap funds. We test the indirect influence of TTO gap funding on spinoffs' sales growth, and we find that TTO gap funding has an indirect positive effect, mediated by the VC financing, on the performance of spinoff companies.

Although, TTO gap funds alone seem not sufficient to drive consistent economic performances in the spinoffs, but it substantially improves the spinoffs position the investment markets playing a certification role.

FORMAL AND INFORMAL INSTITUTIONS IN THE UNIVERSITY TECHNOLOGY TRANSFER PROCESS

Introduction

There is a wide consensus among economists and social scientists on the idea that ‘institutions matter’ for understanding the differences among various economies over time and space (Aoki, 2001; Nelson and Sampat, 2001). Although institutions are nothing more than codified laws, norms and socially accepted convention, badly-performing institutions find difficult to emulate good institutions and implement them.

In a successful economy formal rules are aligned with informal norms and foster entrepreneurial activity. The aim of economic policy must be to re-establish an institutional framework that allows for socially productive entrepreneurial activity to flourish by reducing the cost of engaging in productive activities.

Institutional entrepreneurship and change, however, “poses a problem for institutional theorists, most of whom view institutions as the source of stability and order” (Scott, 2001, p.181). How an institutional field changes? Different authors try to show how and why actors embedded within institutional structures become motivated and enabled to promote change in those structures (Dacin, Goldstein and Scott, 2002; Greenwood and Suddaby, 2006; Seo and Creed, 2002).

In the last thirty years the role of universities in the society’s development is changed. Universities are not more only the locus of research and teaching, but have become a strategic actor in supporting the transfer of their researches’ discoveries and inventions to the social and economic world through valuable products and services, i.e. the technology transfer process. To evidence this tendency, Etzkowitz (1998) coined the term ‘entrepreneurial’ oriented university to describe the tendency of universities to go beyond the provision of graduates and research and, instead, to play a key role for regional economic progress.

The institutional setting heavily influences academic entrepreneurship. For example, the “European Paradox”, i.e. the comparatively limited capacity of the European economies to convert scientific breakthroughs and technological achievements into industrial and commercial successes has been explained mostly with an institutional perspective¹, the

¹ Hart (2001) affirm that the different antitrust and intellectual property regulatory frameworks offer a fertile environment for the marketing of new technologies in the United States, while Smith (2007) highlight as causes

analyses emphasize the ways that organizational and institutional settings shape the use of the innovative inputs. This happens because institutions create powerful pressures for organizations to seek legitimacy and strive for social conformity (Orru, Biggart and Hamilton, 1991).

Field formation is not a static process; new forms of debate emerge in the wake of the change of the society's feeling, causing a reconfiguration of interaction patterns. The emergence of the university entrepreneurship paradigm has been an incremental change, recalling the theoretical idea that institutional evolution involves transitions among three aspects of institutions, which Scott (1995) called pillars: the regulative, normative, and cognitive, together shaping the creation of a new common approach. One aspect may be dominant at any given time, but the three coexist and are interconnected (Hirsch, 1997).

The scope of this paper is to delineate a picture of the institutional elements that changed in the academic entrepreneurship field through an analysis of the literature contributions of the formal and informal institutions acting in the technology transfer process, applying the theory on institutional change developed by Aoki (2001).

Thus, I first conceptualize the institutional setting of university entrepreneurship as the political exchange domain with dynamic institutional complementarities. Then I identify the formal (regulative and normative pillars) and informal (cultural-cognitive pillar) institutions shaping the university technology transfer environment. At the end, I summarize the theoretical contributions of different scholars on university entrepreneurship with the scope of photographing the creation and evolution of the new paradigm and the interaction of the distinct institutions.

The institutional setting of university entrepreneurship

Institutional theory provides a theoretic framework for descriptive models that attempt to explain certain organizational phenomena, it suggests that behaviours are patterned and reproduced because social norms become taken-for-granted. Indeed, institutions can be described as “the rules of the game of a society” (North, 1997, p.6) and the most common definition is: “institutions as systems of established and prevalent social rules that structure social interactions” (Knight, 1992, p.2). Institutions are transmitted by various types of

of a more favourable business environment for technology transfer the higher degree of specialization in R&D intensive sectors and the stronger presence of small and medium-sized R&D intensive firms. Europe, on the other side, seems to be biased by a weaker entrepreneurial culture, greater resistance to organizational change (Delmas, 2002) and barriers to the access to venture capital. The differences in the institutions shaping the systems of innovation form the core of existing explanations of the innovation output-gap (Crescenzi, Rodriguez-Pose, and Storper, 2007).

carriers, including legislation, symbolic systems, relational systems, routines and artefacts, they operate at multiple levels of jurisdiction as a “as system of rules, beliefs, norms and organizations that can jointly generate a regularity of behaviour in a social situation” (Greif, 2006, p.30).

Aoki unifies institutional theory and game-theory with the definition: “An institution is self-sustaining, salient patterns of social interactions, as represented by meaningful rules that every agent knows and incorporated as agents’ shared beliefs about the ways how the game is to be played.” (Aoki, 2001, p.7). He also identifies different game-domain with different institution-agents configuration. The institutional setting of the academic entrepreneurship could be identified in which Aoki (2001) describes as the *political exchange domain*. This prototype domain is composed see the government providing public goods to multiple private agents in exchange for the extraction of costs in the form of taxes. In university entrepreneurship, the public good could be legislation favourable to university technology transfer, or the protection of intellectual property rights to multiple private agents such as the universities, industries, entrepreneurs, venture capitalists and the multitude of subjects rotating around this new institutional environment. When the government changes a formal institution, the private agents may respond by supporting/resisting/submitting to the government’s choice with or without mutual coordination among themselves. A variety of different equilibria can arise depending on the ways in which coalitions between the government and particular private agents, as well as those among the private agents, are formed (Aoki, 2001, Chapter 6). Pejovich (1999, p.170), in his “interaction thesis” on the relations between formal and informal institutions, identifies four possible outcomes: 1) Formal institutions suppress, but fail to change informal institutions; 2) Formal rules directly conflict with informal rules; 3) Formal rules are either ignored or rendered neutral; and 4) Formal and informal rules cooperate.

The outcome between the different possibilities is often influenced by the presence of *dynamic institutional complementarities*. The Momentum Theorem by Milgrom, Qian and Roberts (1991) says that even if the initial support to a new potential institution x is low, the presence of complementary institutions in other domains may amplify the impact of a policy intended to induce x , and that once momentum is initiated, x may gradually evolve as a viable institution. Conversely, even if laws are introduced to induce institution x , the absence of complementary institutions and supporting competence in this and other domains can make its realization difficult (Aoki, 2001, p.267-9). The mechanism is interesting because it

connects the change in the political game-form (the legislation and formal rules) and institutional changes in other domains.

The causation can be bidirectional and social, political, economic and organizational factors can interact rather than operate in unidirectional manner. In this way, the bounded rational agents can transit to a new set of formal and informal institutions, with institutional linkages, complementarities and interdependencies among them.

The way in which institution acts on the objective and subjective perceived reality it's through the three “pillars” of regulative, normative, and cognitive structures (Table 1).

Table 1 - Three Pillars of Institutions

	<i>Regulative pillar</i>	<i>Normative pillar</i>	<i>Cultural-Cognitive pillar</i>
Mechanisms Logic Indicators	Coercive Instrumentally Rules, Laws, Sanctions	Normative Appropriateness Certification, Standards	Mimetic Orthodoxy Common beliefs, Shared logics of action
Relational systems	Governance systems, power systems	Regimes, authority systems	Structural isomorphism, identities

(Scott, 2001, p.52 and p.77, with adaptations)

The regulative element provides explicit guidance to organizational members, often through rules, controls, rewards, and sanctions. The normative element guides behaviour primarily through a less explicit system of social norms and values. It involves the creation of expectations that introduce a prescriptive and obligatory dimension into social life. The cognitive element guides behaviour through the construction of “social identity” (Scott, 2001). It involves the creation of shared conceptions that constitute the nature of social reality through which meaning is made (Scott, 2003). In this construction process, mental scripts and templates guide members to imitate those behaviours they feel will result in positive outcomes and to avoid behaviours perceived to result in negative outcomes. Together, the three pillars structure how important issues are perceived and appropriate actions are developed (Fligstein, 1991).

Generally the studies on institutions, once defined the organizational field and the guiding institutions, describe the forces that drive organizations toward inertia and isomorphism. Indeed, a mature field has stable, routinized interactions between participants who have a strong mutual awareness of which organizations occupy given fields and which do not (Scott, 1994, 2001).

Stability is one aspect of the institutional environment, but institutional structures are never frozen and stability is always transitory (Hoffman, 1999). The organizational field is not static, but it evolves through the entry of particular organizations (Barnett and Carroll, 1995), the alteration of interaction patterns (Greenwood and Hinings, 1996; Hoffman, 1999) and regulatory change (Garud, Jain and Kumaraswamy, 2002). These exogenous “jolts” (Meyer, 1982) “smacking into stable institutional arrangements and causing indeterminacy” (Clemens and Cook, 1999, p.447) precipitate the entry of new players into an organizational field (Thornton, 2002; Thornton and Ocasio, 1999), support the ascendance of existing actors (Scott, Reuf, Mendel and Caronna, 2000), and change the intellectual climate of ideas (Davis et al., 1994). They disturb field-level consensus by raising awareness of extant and alternative logics, enabling the possibility of change (Greenwood and Suddaby, 2006).

North’s view of institutional change (North, 1990, 2005) distinguishes between formal and informal institutions, where formal rules are the laws and policies, often imitated from successful countries, and the informal rules are the norms of behaviour, conventions, self-imposed codes of conduct that generally underlie and supplement formal constraints. He criticizes the mainstream transition strategy for focusing only on formal rules change, overlooking problems of their enforcement and the inertia of formal rules (Chavance, 2008).

With this institutional framework in mind, we review the literature’s contributions describing and investigating various aspects of the new paradigm legitimating university entrepreneurship (Table 2).

Table 2 - Key elements in the institutional perspective to university entrepreneurship.

Formal Institutions	Legislation and policies: <ul style="list-style-type: none"> • Bayh-Dole Act • Intellectual property regulation • Policy and Incentive system • “Publish or perish” dilemma Institutions and infrastructure: <ul style="list-style-type: none"> • Technology Transfer Office (TTO) • Research and Science Park • Business incubators
Informal Institutions	Entrepreneurial universities culture Networks of innovation Faculty / students entrepreneurial attitude

We categorize the influences coming from the regulative pillar and the normative pillar as formal institutions. The contributions studying rules and laws have been classified on the ones related to the Bayh-Dole Act, Intellectual property regulation, Policy and Incentive system

and the “Publish or perish” dilemma. The contributions studying certification and legitimating organizations have been classified by structures: Technology Transfer Office, Science Park and Business incubators.

We categorize the soft pressures related to the cultural-cognitive pillar as informal institutions: Entrepreneurial universities culture, Networks of innovation and Faculty / students entrepreneurial attitude.

Legislation and policies: Regulative Forces

Regulative forces of institutions commonly take the form of regulations. They guide organizational action and perspectives by coercion or threat of legal sanctions (Hoffman, 1999). Under the logic of coercion (Hirsh, 1997), the organizational actors make rational choices among alternative courses of behavior to further their own best interest by maximizing rewards and minimizing adverse outcomes. Organizations accede to them for reasons of expedience, preferring not to suffer the penalty for noncompliance. For example, the Bayh-Dole Act in the United States allows universities to patent inventions funded by federal money and to retain the royalties that the licensing of these patents can generate, giving a whole set of possibilities to universities on how to carry on and exploit technology transfer activities. Through a process of organizational evolution within a regulatory environment, there is a tendency in organizations toward compliance with regulatory force because the material nonconformity would be eventually sanctioned with the extinction.

However, even if a law may change agents’ expectations, whether they will yield a sustainable outcome consistent with the original intention of the legislature cannot be taken for granted. An epistemically objective rule needs to coordinate subjective beliefs of agents and generate cognitive mechanisms among them involving some common elements.

Bayh-Dole Act

The Bayh-Dole Act in 1980 is often indicated as the principal law that regulate the technology commercialization of intellectual property resulting from federal funds in the United States. This legislation allowed universities, non-profit institutions, and small businesses to retain the property rights to inventions deriving from federally funded research. The intent of Congress was to promote collaboration between commercial concerns and non-profit organizations, including universities. Among the Act’s essential purposes are promoting and encouraging the following:

- Use of inventions arising from federally supported research or development;

- Collaboration between commercial concerns and non-profit organizations, including universities;
- Free competition and enterprise without unduly encumbering future research and discovery; and
- Commercialization and public availability of inventions made by United States industry and labor (35 USC § 200).

The 1984 Public Law 98–620 expanded the rights of universities more broadly by removing restrictions in Bayh–Dole and permitting universities to assign their property rights to others (Powell and Owen-Smith, 1998).

In this way the Act allow to the performers of federally funded research a blanket permission to file for patents on the results of such research and to grant licenses for these patents, including exclusive licenses, to other parties, and encouraged universities to develop ‘technology transfer offices’ to market and manage their patentable inventions. The goal of the Bayh-Dole Act was to facilitate the commercialization of university science (Kenney and Patton, 2009; Link et al. 2005, 2007).

Scholar tried mainly to assess the effects of the Bayh-Dole Act on university patenting activity. While at the beginning the extraordinary performance in the US patenting activity² was connected directly with the Bayh-Dole Act, several researches lead to different conclusions that moderate the effect of the legislation: the law is found to affect both the entry rate of universities involved in patenting, and the content characteristics (e.g., applied or basic science) of the patents (Mowery, Nelson, Sampat and Ziedonis, 1999, 2001, 2004; Nelson, 2001; Mowery and Sampat, 2001a, 2001b, 2005; Sampat, Mowery and Ziedonis, 2003; Coupe, 2003; Shane, 2004). Tyler (2011) even moves a critique on how the Act as been implemented affirming: “Unfortunately, too often universities and their leaders focus on the tactics provided for in the Act and lose sight of the Act’s broader purposes of preventing non-use of research results funded with government dollars and encouraging commercialization, utilization, and public availability of those results.”

However, it is apparent that the Bayh-Dole Act provided a strong political endorsement of the argument that failure to establish patent protection over the results of federally funded university research would limit the commercial exploitation of these results. The

² The number of patents issued to U.S. universities more than doubled between 1979 and 1984, more than doubled again between 1984 and 1989, and more than doubled again over the 1990s. The number of universities with technology licensing and transfer offices increased from 25 in 1980, to 200 in 1990, and by the turn of the century virtually every American research university had such an office. Over this same period, university licensing revenues have increased greatly, from \$221 million in 1991, to \$698 million in 1997 alone (Nelson 2001).

policymakers believed (correctly, considering the subsequent developments) that stronger protection for the results of publicly funded R&D would accelerate their commercialization and the realization of economic benefits.

The contribution of the Bayh–Dole Act to society remains mixed on the societal impact (Verspagen, 2006). The strongest criticisms found little systematic evidence of a destruction of the open culture of science or to support the assertion that universities are performing less basic research (Welsh et al., 2008). Indeed, the enactment of Bayh–Dole in the U.S. resulted in nearly all major research universities establishing a technology transfer office, with an increasing attention to academic patents and to licensing the results (Grimaldi et al., 2011).

In Europe, instead, the law on technology transfer is fragmented; the practices among European universities are diverse and uncoordinated. University research is mostly subsidized by the states, and the laws failed to ensure that knowledge, produced as a result of public funds would contribute to the universities research fund by means of patenting the results and institutionalizing the monetization practices. Many European academic researchers are only hesitantly, if at all, interested in the exploitation of their research in the private sector (Siepmann, 2004). Mowery and Sampat's (2005) paper examines the effect of Bayh-Dole on university-industry collaboration and technology transfer in the United States, and concludes that efforts to emulate the Bayh-Dole in other OECD countries are likely to have modest success at best without greater attention to the underlying structural differences among the higher education systems of these nations.

However, several countries have attempted to enact legislation similar to the Bayh-Dole Act supporting technology transfer and university commercialization of publicly funded research, but the results at now have not the same impact of the U.S. counterpart. Examples are the reforms of the entire academic system introduced in the U.K. and in the Netherlands during the 1990s, the so called Loi Allègre of 1999 in France, Swedish Government's efforts to promote university technology commercialization since the beginning of the 1980s, and the transfer of several powers from the central Government to universities in Italy (Baldini et al., 2006). Indeed, Denmark, Germany, Belgium, Austria, and Norway reformed their intellectual property laws to grant IP rights to universities in a manner similar to Bayh–Dole (So et al., 2008; Agres, 2002).

Intellectual property regulation

The codification of standard, enforceable policies provides a clear indicator of institutionalization (Stinchcombe, 1965). Colyvas (2007) reported that at Stanford, considered

as a benchmark in the U.S., by 1982 was already present a coherent set of practices that became standard for the university and reflected the selective retention of some features of the early models, and the demise of others. Property rights are affected by social-contractual commitments and organizational standards, the barriers for universities to adjust their policy and organizational forms to technology commercialization come from internal and external parties' adherence to university's historic commitment to the intellectual commons (Argyres and Liebeskind, 1998).

The rationale for intellectual property regulation is to capitalize on the economic relevance of the research results, getting the private benefits at the expense of making them freely available to the society.

Traditionally, industry and university have differing objectives regarding intellectual property. As explained by Brainard (1999, p.9): "The goal of business and universities in producing and protecting intellectual property is innovation for the production of revenue. Beyond this ultimate shared goal, the interests of universities and businesses diverge. Universities value intellectual property not only as a revenue-producing resource, but also as a tool in the advancement and dissemination of knowledge". Scientists believe university IP policies should shield their work from opportunistic behaviour and at the same time be designed to attract industry partners (Welsh et al., 2008).

Along this line of thought, ten years ago various scholars expressed doubts about university policy on intellectual property having excessive commercialization concerns that could threaten university's integrity and the traditional university goal (Powell and Owen-Smith, 1998; Conceicao et al., 1998; Del Campo et al., 1999; Steffensen et al., 2000; Hall et al., 2001; Owen-Smith, 2003). In a research, scientists criticize that universities use IP policies primarily as revenue raising vehicles and secondarily to address public good issues such as technology transfer (Welsh et al., 2008).

More recently, the widespread adoption of technology transfer programs in U.S. universities reflected a new form of organizing research and development, legitimizing the university intellectual property protection on academically generated research finding and the involvement of universities in marketing and licensing research findings to industry (Colyvas, 2007).

Colyvas et al. (2002) affirm that, in the case of embryonic invention, technology transfer would probably not have occurred without intellectual property protection. Debackere and Veugelers (2005) provide a framework of governance structure that captures the formation of effective mechanisms. It encompasses an appropriate organizational structure with

unambiguous regulation of ownership titles and property rights, an appropriate mix of incentive mechanisms targeted to the research group and individual researchers, decentralized management style, and a matrix structure for the interface/ liaison.

Lockett and Wright (2005), studying U.K. universities, affirm that both the number of spin-out companies created and the number of equity investments in existing spin-outs are positively associated with university's expenditure on external intellectual property protection and the royalty regime of the university.

Baldini et al. (2006) find that in Italy patenting activities almost tripled in universities with an internal IPR regulation, after controlling for several universities' characteristics, previous patenting activity and time trends; and each time a university creates its own patent regulation, there is a 9% increase in the likelihood that universities without any internal patent regulation will adopt one. Moreover, university-level patent regulations reduce the obstacles perceived by inventors, as far as they signal universities' commitment to legitimate patenting activities (Baldini et al., 2007).

Incentive system

"Institutions are incentive systems, that's all they are. It is important to understand that because being incentive systems, they provide a guide to human behaviour." (North, 2003). The transformation of the norms and incentive system of the academy and its impact on the expansion of science has been criticized (Krimsky, 2003; Washburn, 2005) and appreciated (Lach and Shankerman, 2003; Shane, 2004).

The main critics have been the one moved by Markman et al. (2004) who suggested that monetary incentives given to university scientists are negatively related to the number of equity licenses in young ventures, and to the number of start-ups; similarly, sharing revenues with scientists' departments is negatively related to the number of incubators.

The strand of work on how the procedures and reward systems are aligned to encourage commercialization sees the contribution of Colyvas (2007) and Owen-Smith and Powell (2001). They affirm that the faculty decisions to disclose are shaped by their perceptions of the benefits of patent protection and, in particular, the incentives are influenced by the perceived costs of interacting with technology transfer offices and by institutional environments (supportive or oppositional to commercialization). The most significant benefits by faculty members to collaborate with firms is complementing their own academic research by securing funds for graduate students and lab equipment, and by seeking insights into their own research (Lee, 2000). Friedman and Silberman (2003) proposed that royalties granted to

faculty inventors have positive effect on the number of licenses, while royalties granted to the inventors' departments have a negative effect. Siegel et al. (2003b) and Brouwer (2005) find, among the characteristics of research universities that affect the number of invention disclosures and the productivity of technology transfer offices, the reward systems for faculty involvement in university-industry technology transfer activities. From this studies emerge that university inventors have greater incentives to invent if they can fully appropriate the gains from invention. Using panel data, Lach and Schankerman (2003) found that royalty shares have a positive and significant incentive effect on license revenues, and a negative (not significant) effect on disclosures.

Baldini (2010) finds that the royalties shared with the inventors and their departments are associated with greater patenting activity. Although, the major motivations to patent for scientists are prestige, reputation and knowledge exchange. Indeed, universities rely almost exclusively on royalties, researchers are sensitive to diverse incentives, whose importance varies according to both personal characteristics and the context.

Feldman and Desrochers (2003) link the general lack of incentives and encouragement for commercial activity at John Hopkins university with the presence of no highly visible economic benefits for the local area.

Henrekson and Rosenberg (2001) and Goldfarb and Henrekson (2003) identify among the weaknesses of the Swedish incentive and institutional structure the low incentives to become an entrepreneur and to expand existing entrepreneurial ventures and the low incentives within the university system to become more entrepreneurial, affirming that the top-down nature of Swedish policies of commercializing university inventions and Swedish academic environment discourage academics in actively participating in the commercialization of their inventions.

“Publish or perish” dilemma

There has been a growing concern about the impact that application-driven research may have on the conduct of science. Some scholars argue that the involvement of academic scientists in commercial activities modify their research attitude, motivating researchers to undertake projects with greater economic and social relevance (Gibbons et al. 1994, Ezkowitz 2004). Geuna and Nesta (2006) fear adverse effects that might have a negative impact on the quality of the science and distinguish five possible impacts of increased university patenting (Meyer 2006):

1. A substitution effect between publishing and patenting. Particularly important is the possibility of different impacts depending on the seniority of the researchers involved.
2. A threat to teaching quality (as senior faculty members focus on patenting rather than teaching in the light of changing structures).
3. A negative impact on the culture of open science, in the form of increased secrecy and a reduced willingness to share data with peers, delays in publication, increased costs of accessing research material or tools, and so on.
4. Diverting research resources (researchers' time and equipment) from the exploration of fundamental long-term research questions.
5. A threat to future scientific investigation from IPR on previous research. In theory, patent law provides an exception from patent infringement for 'research and experimental use' that allows university researchers to use patented inventions for their research without being obliged to pay license fees. However, this exception can be weak if the firm that obtains the exclusive right to exploit a patent decides that the research exception is not applicable to university projects financed by industry.

On the other hand, following Zucker and Darby (1995, 1996, 2001, 2002), one could argue that entrepreneurial or technological activity and scientific excellence or productivity are mutually reinforcing. Indeed, the authors show that 'star scientists' from universities had a key role in the birth and growth of the biotechnology industry by playing dual roles as entrepreneurs and research scientists. Buenstorf (2009) finds that patents and publications positively correlated. Fabrizio and Di Minin's (2008) results suggest that publication and patenting are complementary, not substitute, activities for faculty members. Similarly, Van Looy et al. (2004) find that entrepreneurial and scientific performances do not hamper each other, the engagement in entrepreneurial activities coincides with increased publication outputs without affecting the nature of the publications involved.

Baldini (2006a) proposes that university patenting activities have positive influence on researchers' careers, prestige and earnings, additional research funds, access to other proprietary technology, equipment, exchange of knowledge with industrial researchers. Although, he recognizes also negative effects include undermining the culture of open science, diverting resources from long-term fundamental research, diverting resources from teaching activity and reducing its quality. He finds (Baldini, 2006b) that the surge of university patents happened neither at the expense of their quality, nor of the quality of research. Scientific excellence and technology transfer activities seem to mutually reinforce. In another paper (Baldini, 2010), he rejects that publications and spin-offs are substitutes.

Lacetera (2009) compare academic scientist and profit-seeking company inventor in commercializing research and finds that the direct benefit that academic scientists derive from the performance of pre-commercial research (publications) reduces the likelihood that they will engage in commercialization. In fact, unlike the industrial researcher, the academic scientist receives direct benefit from performing research, in the form of publication and peer recognition. So academic scientists will tend to commercialize projects with higher expected revenues than do industrial actors.

Shelton and Leydesdorff (2012) demonstrate with an econometric model that government funding and spending in the higher education sector, encourage publications, whereas industrial funding and spending in the business sector, encourage patenting.

Institutions and infrastructure: Normative Forces

Normative influence arises from both values and norms (Scott, 1995). Values and norms may originate in one organization as responses to the environment and then diffuse to other organizations as they adopt them in a quest for legitimacy (Hinings, Thibault, Slack, and Kikulis, 1996). At first, following an exogenous shock in the academic entrepreneurship environment, depicting a general trend and not constraining academic institutions through a formal law, academic organisations legitimated themselves by using mimetic processes, replicating the behaviour of highest status ones (Baldini, Grimaldi and Sobrero, 2010). An example is the consequent spread around U.S. with an isomorphic process of the creation of technology transfer offices after the ones at MIT and Stanford received great visibility.

Subsequently, once constrained by a formal regulation/law such as the Bayh-Dole Act, the academic organisations relied on the professionalization of their members. The normative influences can be thought of as a “logic of appropriateness,” defined in terms of a social interaction context that identifies appropriate behaviour for group members (Hirsh, 1997). The normative forces, developing through social interaction, develop, solidify, and are diffused as a function of time. Their ability to guide organizational action and beliefs stems largely from social obligation or professionalization (Hoffman, 1999).

Normative influences for academic organisations to create new entities to carry on technology transfer activities originated both inside and outside. The social networks that include organizational members and non-members can be a source of normative influence as well as a source of information, in fact “Actors do not behave or decide as atoms outside a social context, nor do they adhere slavishly to a script written for them by the particular intersection

of social categories that they happen to occupy. Their attempts at purposive action are instead embedded in concrete, ongoing systems of social relations” (Granovetter, 1985, p.487).

Other sources of normative influence from outside the organization include professional organizations that frequently seek voluntary compliance with standards for operation (Scott, 1995). For example, the professional managers running Technology Transfer Offices exhibit great similarity and bring professionalization into the university environment since they refer at the same professional networks (e.g., AUTM – Association of University Technology Managers). As explain by Di Maggio and Powell (1983, p.152): “Such mechanisms create a pool of almost interchangeable individuals who occupy similar positions across a range of organizations and possess a similarity of orientation and disposition that may override variations in tradition and control that might otherwise shape organizational behaviour”.

Furthermore, implicit stakeholder norms and values are related to the issue of legitimacy. Not knowing when stakeholder support may be sought in the future, the organization members’ behaviour is limited by the implicit normative boundaries perceived to be important to the various stakeholders. Stakeholders force the adoption of models that are deemed valuable and commendable in realm in which the organization operates, providing in exchange the access to resources.

The Technology Transfer Offices

In the last decades, “almost all research universities in the USA and Europe have established technology transfer offices to commercialize their intellectual property” (Siegel et al., 2007, p.640) with an isomorphic process that shows academic organizations legitimate themselves replicating the behavior of highest status ones, but often also directly experiment different commercialization methods and learn from the experience.

The isomorphism results from the normative influences of authoritative sources. The organizational need to obtain and maintain legitimacy took universities to deal with the uncertainty related to the new paradigm through the imitation of the MIT and Stanford approaches. Meyer and Rowan (1977, p. 349) recognized that when an organization enhances its social acceptance or legitimacy by “acting on collectively valued purposes in a proper and adequate manner” it increases its access to resources and exchange possibilities with other organizations, thereby increasing its likelihood for survival (DiMaggio and Powell, 1983). Indeed, legitimacy facilitates the acquisition of other resources essential for the genesis, evolution, and maturation of new organizational forms such as capital, technology, managers, competent employees, customers, and networks.

Technology transfer offices (TTOs) seek to market intellectual property to established technology-driven firms or spinoffs created around the licensed technology. TTOs implement different activities depending on their strategy, resources and purposes (DeGroof and Roberts, 2004; Clarysse, Wright, Lockett, Van di Velde, and Vohora, 2005) and act as institutional entrepreneurs in building legitimacy for novel technologies (Jain and George, 2007). The role of TTOs can be described as “intermediary” between the suppliers of innovations, university scientists, and those who can potentially commercialize them, i.e. established firms, entrepreneurs, and venture capitalists. The establishment of effective internal and external communication links to sources of scientific and technological knowledge and to industry is identified as a key factor for success in the innovation process (Tidd et al., 1997).

Regarded as the formal gateway between the university and industry, TTOs have been in the spotlight of the stream of researches that views university entrepreneurship as a function of their TTOs systems, structure, and personnel’s experience (Jones-Evans and Klofsten, 1999; Chapple et al., 2005). A voluminous and growing body of research has emerged documenting the impact of TTOs on the commercialization of university research (Lockett et al., 2003, 2005; O’Shea and Rory, 2008; Phan et al., 2005; Siegel et al., 2007). Most of these studies focus on various measures associated with university TTOs (Mustar et al., 2006; Mosey and Wright, 2007; Shane 2004; Powers and McDougall, 2005; Phan and Siegel, 2006; Di Gregorio and Shane, 2003; Mowery et al., 2004). By most accounts, the impact on facilitating the commercialization of university science research has been impressive (Aldridge, Audretsch, 2011).

Powers and McDougall (2005) propose policy orientation effects on the TTOs’ performance and Decter et al. (2007) find significant differences in the motivations of U.K. and U.S. university TTOs to transfer technology, the consistency of university technology transfer policies and the accessibility of university technologies to business.

For Clarysse et al. (2005), the existence of different organizational goals and different environments and strategies adopted by research and development organizations take to the formation of three distinct types of spin-out models. Clarysse et al. (2004) argue that an alternative policy approach in the light of both difficult to surmount resource constraints and variability in spin-off opportunities is for universities to match their objectives for spin-offs to their contexts. Universities should, however, adopt multiple but separate spin-off policies where they have new spin-off opportunities that range from modest self-employment to high growth potential cases. DeGroof and Roberts (2004) too examine different policies in terms of the extent to which they engaged in origination, concept testing and startup phase

activities, and identify four archetypes of spin-off policy: an absence of proactive spin-off policy; minimalist support and selectivity; intermediate support and selectivity; and high support and selectivity. They propose that spin-off policies in academic institutions do affect the growth potential of ventures and suggest that environments with weak entrepreneurial infrastructure and culture require academic spin-off policies involving high selectivity and high support in order to generate growth oriented ventures.

Table 3 - Institutional effects associated with the Technology Transfer Offices in different countries (adapted from Rothaermel et al., 2007).

Main Studies	Impact / effect	Where
Jones-Evans et al. (1999)	The general role and function of the industrial liaison office in Sweden is to be part of a network of technology-transfer organizations, acting as a gateway to areas of expertise. While in Ireland, the system is more centralized and the industrial liaison offices are directly responsible for the technology transfer function.	Sweden, Ireland
Collins and Wakoh (2000)	One of the Japan's barriers in university technology transfer is the lack of complementary and intermediary institutions that can facilitate transferring technologies.	Japan
Thursby et al. (2001)	The most important objectives of the TTO are obtaining royalties and licensing fees. When technology is licensed at an early stage, royalties are lower and sponsored research is preferred. When TTO evaluates the technology as not very important, licensing agreement is less likely to include sponsored research.	U.S. universities
Meseri and Maital (2001)	The criteria for Israeli TTOs to decide on technology transfer projects are similar to venture capitalists and TTO at MIT (factors that score highest include market need, market size, etc). For the criteria of success/failure, Dimotech focuses on the characteristics of the individuals involved in launching a new venture, but most other Israeli TTOs focus on licensing; the former is closer to the criteria used by Venture Capitalists.	Israel
Bercovitz et al. (2001)	Technology transfer activities (e.g., eliciting and processing invention disclosures, licensing university-created knowledge, seeking additional sponsorship of R&D projects) are shaped by the resources, reporting relationships, autonomy, and/or incentives of technology transfer offices.	Johns Hopkins University, Pennsylvania State University, and Duke University, U.S.
Thursby and Thursby (2002)	The increase of university commercial output comes from an increase in faculty propensity to disclose and apply for patents. This increase is small in comparison to high increase of administrators' propensity to license.	U.S. universities
Colyvas et al. (2002)	TTO's marketing activities are the most important for inventions in technological areas where existing links between academia and industry are weak.	
Feldman et al. (2002)	Universities are more likely to use equity as they gain experience in licensing (or get older), but the relationship has an inverted U shape in which the use of equity decreases when the university has executed a large number of licenses. Other factors affect the use of equity: industrial research support (+), the dependency of TTO on the university (-), and experience relative to other institutions (+).	Carnegie I and II research universities, U.S.
Jensen et al. (2003)	Technology transfer office (TTO) balance the objectives of the university and faculty, proving to be the agent of both faculty and university administration. TTOs' objectives are influenced by	U.S. research universities

	both of them.	
Jackson and Audretsch (2004)	The Indiana University Advanced Research and Technology Institute (ARTI, the technology transfer organ of the Indiana University System) contributes to Indiana's economic landscape through technology transfer, economic development programs and job creation. This case study focuses on the formation of ARTI, its structure and mission, recent initiatives, and metrics for technology transfer initiatives (e.g., revenue metrics and throughput metrics).	Indiana, U.S.
Markman et al. (2005a)	The faster TTOs can commercialize patent-protected technologies, the greater their licensing royalties and the more new ventures they spin off. TTO resources, their competency in identifying licensees, and participation of faculty-inventors in the licensing process determine the speed.	U.S.
Markman et al. (2005b)	For-profit university technology transfer offices structures are positively related to new venture formation. Traditional university and non-profit TTO structures correlate with the presence of university-based business incubators.	U.S.
Chapple et al. (2005)	Invention disclosure, total research income, the number of technology transfer employees, and protection of licensee affect TTO's licensing performance. Regions with a higher R&D intensity, younger TTOs, and universities with medical schools are more efficient at generating new licenses.	U.K. universities
George (2005)	Changes in efficiency (cost of patenting) is driven by changes in routines and processes (experiential learning). When cumulative experience increases, routines in a primary capability may impede the efficient deployment of complementary capabilities.	Wisconsin Alumni Research Foundation, U.S.
Degroof and Roberts (2004)	Spin-off policies involving strict selectivity combined with high support aid ventures capable in exploiting opportunities. Spin-off policies with low selectivity and low support predispose ventures to adopt small and medium enterprise formats. Spin-off policies involving strict selectivity combined with high support are more suited to environments with weak entrepreneurial infrastructure and culture, but require a significant amount of resources.	Belgium
Leitch and Harrison (2005)	Roles of TTO in second order spin-outs: supports their development and takes equity stakes in them. The original parent/incubator organization can continue to play a role in channeling resources into start-up ventures and providing legitimacy and credibility for them.	Queen's University
Lockett and Wright (2005)	Both the number of spin-out companies created and the number of equity investments in existing spin-outs are positively associated with university's expenditure on external intellectual property protection, business development capabilities of TTO, and the royalty regime of the university.	U.K. universities

Research and Science Park

University research parks were established to stimulate and to facilitate technology transfer and the creation, growth, and development of high technology firms (Bakouros et al., 2002). Both universities and government support research and science parks, for different reasons: universities in order to enhance their prestige, secure additional funding from the private sector, generate rental income, ensure that university research is more relevant to industry, and to provide job opportunities for students and post-docs; government provides financial

support because they view such institutions as a mechanism for generating technological spillovers and employment growth (Leyden, Link, and Siegel, 2008).

The U.K. Science Park Association (UKSPA) reports that there are 100 science parks in the U.K., most of which are based on or near U.K. universities. Phan, Siegel, and Wright (2005) identified over 200 science parks in Asia, including 111 in Japan alone. China has also been recently active in this arena.

Of the population of 81 university research parks reported in 2002 in the U.S. (Link and Scott, 2003), 20 percent are focused exclusively on biotechnology and 17 percent are single focused on information technology. The U.S. parks vary substantially in size: for example, Research Triangle Park in North Carolina currently has 45,000 employees working on 7,000 acres and Colorado Bioscience Park in Aurora currently has 50 employees on 147 acres. Link and Scott (2003a, 2003b, 2005, 2006, 2007) report that U.S. science parks have changed the research environment at American universities. University provosts report that since these parks have opened university research output (publications and patents) and extramural research have increased. It also appears as science parks have resulted in the university curriculum has become more applied. Park's growth equates to the adoption of innovation by companies and an higher proportion of university spin-offs are founded in older parks, parks associated with richer university research environments, parks located closer to their university, and parks with a biotechnology focus.

The firm-level decision to locate on a university research park has been investigated by Leyden, Link, and Siegel (2008). The key empirical implication of their theoretical model is that firms conducting "higher quality" research are more likely to locate on a university research park, because this will enhance the company's ability to absorb new knowledge.

Lindelöf and Löfsten (2002, 2003, 2004, 2005), on the Sweden context, find that on-science park firms and off-science park firms are different in terms of innovation and marketing. Moreover, science park-based firms put greater emphasis upon access to equipment, R&D and personal categories, are more involved in cooperation with universities, rate basic and applied research more highly, and have higher network activities.

Palmai (2004) describes the creation of an innovation park, INNOTECH of the Budapest University of Technology and Economics and Salvador (2011) report the Turin case study.

Quintas et al. (1992) point out the two main deficiencies of the science park model: mismatches between academic research output and R&D needs of science park firms and the science parks' restriction on manufacturing activity. Siegel, Westhead, and Wright (2003a, 2003b) critical the positive impact of science parks: they find that the returns to being located

on a science park are negligible and, even if in-park firms have slightly higher research productivity than that off-park firms, this difference is not so strong after controlling for endogeneity bias.

Business incubators

Business Incubators (BI) are believed to be an effective policy instrument for supporting the growth and development of technology based firms (Vedovello and Godinho 2003; Chan and Lau 2005; Soetano and Jack 2011).

The BIs infrastructure has changed with time (Barrow 2001; Hackett and Dilts 2004; Bruneel et al. 2012), going from affordable office facilities and shared resources to potential new firms to more sophisticated business support services (Hindle and Yencken 2004; Colombo and Grilli 2005). Nowadays, great emphasis is placed on developing access to networks and networking capabilities (Patton et al. 2009, Peter et al. 2004, Ratinho et al. 2009). Working together in the same building with other incubator firms can create synergy, embedded relations and social capital, all elements thought to enhance a firm's innovative capabilities and increase the potential for commercial collaboration (Hansen et al. 2000). Such interactions may also aid the exchange of resources, knowledge and information and so help address the liability of newness and smallness that all incubator firms experience. Moray and Clarysse (2005) conclude that the development of a successful incubator requires continuous organizational learning.

Prior research has focused on incubator development and configuration (Kuratko and LaFollette 1987; Allen and McClusky 1990; Campbell and Allen 1987; Clarysse et al. 2005), and measures to assess the impact and influence of the incubation process on economic development (Smilor and Gill 1986), innovation (Acs and Audretsch 1992), the creation of new high quality jobs and profit generation (Reynold et al. 1994, Mian 1994, 1996a, 1996b, 1997). Lee and Osteryoung (2004) list the main factors that contributes to the effectiveness of university business incubators, among them and find no significant differences between US and Korean incubators.

The majority of studies support a positive outcome from the incubation process, but others question the support BIs provide (Colombo and Delmastro, 2002; Tamasy, 2007), their quality (Aernoudt, 2004, Von Zedtwitz and Grimaldi, 2006) and the misalignment of incubator and incubatee objectives (Hackett and Dilts, 2004). Rothaermel and Thursby (2005a, 2005b) found little evidence of localized spillovers between Georgia Tech and incubator firms.

Informal institutions: Cognitive Forces

Cognitive-cultural aspects of institutions embody cultural rules and frameworks that guide understanding of the nature of reality and the frames through which that meaning is developed (Hoffman, 1999). Organizations will often abide by them without conscious thought (Zucker, 1983). Cognitive institutional aspects form a culturally supported and conceptually correct basis of legitimacy that becomes unquestioned (Selznick, 1996). The cognitive pillar of institutional theory has logic of “orthodoxy” (Hirsh, 1997), providing guidelines by specifying the forms and procedures an organization of a particular type should adopt if it is to be seen as a member-in-good-standing of its class.

North’s view of institutional change (North 1990) underlines the inertial character of the informal institutions, observing the persistence of many aspects of a society in spite of a total change in the formal rules. Defining institutions as constraints, he notes that “informal constraints that are culturally derived will not change immediately in reaction to changes in the formal rules,” leading to a “tension between altered formal rules and the persisting informal constraints” (North 1990, p. 45). While changes in formal rules are made and enforced by the polity, informal constraints are linked to cultural inheritance: “Economies that adopt the formal rules of another economy will have very different performance” because of “different informal norms and enforcement” characteristics (North, 1994, p. 366). This discrepancy results in putting limits on expected revolutionary (formal) changes and in disappointment in terms of performance when imitating formal rules of successful countries.

This approach could explain the differences still existing in the university technology transfer between the two continents. In fact, despite the recent and rapid formal institutional-building efforts at EU level, the informal institutions still lag behind.

Entrepreneurial university culture and policy

The entrepreneurial university culture (Etzkowitz, 1998) corresponds to the sociological notion of “social embeddedness” (Granovetter, 1986). Granovetter (1986) argues that “agents in markets and organizations in the modern society generate trust and discourage malfeasance by being embedded in concrete personal relations and structures (networks).” The norms and values are not a one-time influence but an ongoing process, continuously needing to be constructed and reconstructed through interactions.

The cognitive effects of the new university-industry linkages, the closing gap between research and capitalization of knowledge has encouraged scientist faculty to look at their research results from two perspectives: traditional and entrepreneurial. Etzkowitz believes

that the future role of the university globally is an entrepreneurial university³ with an academic structure and function that is based on an alignment of economic development with research and teaching as academic missions. In his vision, a university transit from a research university into the entrepreneurial university endogenously since the internal organization of a research university consists of research groups that have firm-like qualities, when research funding is awarded on a competitive basis (Etzkowitz, 1998, 2003, 2004; Etzkowitz et al., 2000; Etzkowitz and Klofsten, 2005). Grigg (1994), on the same vein, affirm that universities need to be entrepreneurial if they want to fulfil and sustain their role and purpose in society, which is to foster creativity and responsiveness to change in cultural and ethical as well as in scientific, technological and economics dimensions.

Entrepreneurial universities play an important role as knowledge-producer, a disseminating institution and a promoter of multiple support measures for entrepreneurship (Guerrero et al., 2008; Guerrero and Urbano, 2012). Entrepreneurial universities are involved in partnerships and networks with public and private organizations that are an umbrella for interaction, collaboration, co-operation (Inzelt, 2004). They implement several strategies and new institutional configuration to work together with the government and industries to facilitate the generation and exploitation of knowledge and technology (Leydesdorff and Meyer, 2003). In the literature, theoretical models have tried to explain the phenomenon of entrepreneurial universities (Clark, 1998; Kirby, 2005; O'Shea et al., 2005). At the same time, some empirical studies have analyzed this phenomenon in universities from Australia (Zhao, 2004), Canada (Keast, 1995), China (Eun et al., 2006), Japan (Yokoyama, 2006), Germany (Audretsch and Lehrmann, 2005), Italy (Baldini et al., 2006), Netherland (Lazzeretti and Tavoletti, 2005), Sweden (Jabob et al., 2003), Ireland (Klofsten and Jones-Evans, 2000), Belgium (Ranga et al., 2003; Debakere and Veugelers, 2005), United States (Smilor et al., 2007), among others.

Universities' approach to knowledge transfer is shaped by institutional and organisational resources, in particular their ethos and research quality (Hewitt-Dundas, 2012), then "as we increase our understanding of the actors involved and the potential outcomes, it might be possible to craft policy that selects for the outcomes the public deems most attractive" (Welsh et al., 2008, p. 1863).

Eun et al. (2006) are critical about the Triple Helix perspective studying the China framework. They affirm that the basic determinants for university–industry relationships are

³ Term used to describe universities that have improved different mechanisms to contribute to regional development and increase their incomes.

internal resources of university, absorptive capacity of industrial firms and existence of intermediary institutions, as well as the propensity of university for university-run enterprises. Siegel et al. (2003, 2004) indicate as barriers to university–industry technology transfer culture clashes and bureaucratic inflexibility.

Network of innovations

Technology ventures, particularly in knowledge-intensive sectors, place more emphasis on information, knowledge accumulation and learning than non-technology ventures which largely focus on access to relatively static external resources such as financing, manufacturing capacity, and distribution channels. The growth of technology ventures is dependent on human resources and can be viewed as a process of acquiring, configuring, and reconfiguring these resources. So it's important to establish a good network to be more able to generate novel ideas and identify business opportunities, access necessary resources and exchanging information, and then initiate a series of activities that lead to technology success commercialization and ventures creation (Walter et al., 2006; Rickne, 2006; Wright et al., 2004; Shane and Stuart, 2002; Perez Perez and Sanchez, 2003). Spin-offs' collaborations with parental organization result in the access to technological competencies and helps the spin-off process by providing infrastructures and expertise (Grandi and Grimaldi, 2003, 2005; Gubeli and Doloreux, 2005, Nicolaou and Birley, 2003a, 2003b; Westhead and Storey, 1995). The network relations between the spin-offs and the university consist of a small number of strong ties that are characterized by a high degree of trust and informality. Strong ties are fruitful for the transfer of complex knowledge and they cost less than building an intensive social network (Johansson et al., 2005)

Furthermore, the exploitation of entrepreneurial opportunities involves making decisions under uncertainty and limited information about product, markets, ways of organizing, strategy and the acquisition of resources (Shane, 2004). The skills and information necessary to make these decisions are often unavailable in codified form, but often can be learn through observation of others, thus justifying the creation of university accelerator where spin-offs share the venture creation process (Busenitz and Lau, 1996).

As a society develops, its social capital must adapt as well, allowing the interpersonal networks to be partially replaced with the formal institutions of a market-based economy, such as a structured system of laws imposed by representative forms of governance (Stiglitz). Many authors had underline that the network supporting infrastructure in Silicon Valley is really sophisticated and has evolved to become a strategic planner and a management

consultant. Many companies do succeed because the network works to help companies' growth: they help them find new customers, refinancing and find new managers if necessary, merge with other companies to be successful (Kenney, 2000). Among the actors that influence the technology commercialization, the venture capitalists are the private investors willing to invest in innovation. Samila and Sorenson (2010) reveal that the positive relationships between government research grants to universities and research institutes and the rates of patenting and firms formation in a region become more pronounced as the supply of venture capital in that region increases. Consistent with perspectives that emphasize the importance of an innovation ecosystem, the findings point to a strong interaction between private financial intermediation and public research funding in promoting entrepreneurship and innovation.

The research universities could play an important role in the cluster formation process: these institutions constitute a source of knowledge spillovers via the transfer of human capital, which occurs mainly through students. It appears that when students are placed in innovative firms within a cluster, they disseminate tacit knowledge that turns out to be a critical ingredient for innovative performance in a regional technology cluster (Rothaermel and Ku, 2008; Audretsch and Lehmann, 2005; Segal, 1986; Bania et al., 1993; Friedman and Silberman, 2003). Even if most academics engage with industry to further their research rather than to commercialize their knowledge (D'Este and Perkmann, 2010), most successful transfers are based on strong prior connections between people in the laboratories and in the business communities (Harmon et al., 1997; Murray, 2004).

Faculty / students entrepreneurial attitude

At the individual level, the emergence of distinctive forms, processes, strategies, outlooks and competencies appearing from patterns of social interaction and adaptation are driven by the need to respond to environmental pressures (Selznick, 1996).

University entrepreneurship has been strongly supported by the initiative of small groups of researchers that believed in the benefit to commercialize the results of their research activity. Although a majority of faculty can be expected to generate ideas of potential commercial value, only a smaller fraction of them act to commercialize the ideas (Roberts and Peters, 1981; Louis et al., 1989; Chrisman et al., 1995; Lee, 1996; Grandi and Grimaldi, 2005).

When a technological opportunity arises, the academic can continue his/her research activities, publishing, patenting or teaching or he/she can follow new goals like wealth and economic development. Entrepreneurship can be seen as the process in which actors interact

in such a way that opportunities are recognized, preparatory steps are taken in order to exploit the recognized opportunity, and, subsequently value is created (Shane and Venkataraman, 2000).

The motivations of the scientist-entrepreneur are different from not academic entrepreneurs: the traditional reasons that push an individual to become entrepreneur such as the achievement motivation and the self-confidence, i.e. the will to develop a successful business exploiting his own competences and trusting his own capabilities (Locke and Baum, 2007), are not valid for the scientist-entrepreneur. Instead, the decision of an academics to start a business activity is influenced mainly by two elements: on one side the scientists identify market opportunities unexploited for the discoveries they made in the research laboratories and they feel a need to apply knowledge into practical applications; on the other side they are interested in the economic profit, but seeing it as a mean to bring their research projects to completion, to create grants for doctoral students and researchers and to buy infrastructures and laboratory instruments to fast forward their studies, more than a private gain (Chiesa and Piccaluga, 2000, Fini et al., 2009; Hsu et al., 2007; Colombo and Grilli, 2005).

Research has shown that a critical human capital resource for the development of cutting-edge technologies is access to persons with expert knowledge and talent (Powers and McDougall, 2005; Gimmon and Levie, 2010). Zucker et al. (1998) argues that ‘star’ scientists from higher quality academic institutions create spinoff firms to capture the rents generated by their intellectual capital. So usually the inventors, as founders of the spin-off, are involved in the process of technology commercialization but they have great difficulties to figure out the potential market and customers for the inventions without a business background. Thus, not only the human capital, but also the social capital of the scientists-entrepreneurs becomes important for the success of the technology commercialization, and faculty participation through informal and formal channels is important to licensing process. (Mosey and Wright, 2007; Hsu, 2007; Thursby and Thursby, 2004).

Markman, Gianiodis, and Phan (2008) analyze a growing phenomenon at American universities: university-based scientists who “bypass” their institution’s licensing office, by privately selling or licensing scientific discoveries that were developed at their institutions. The study shows that increased bypassing activity is associated with more valuable discoveries and heightened entrepreneurial activities, suggesting that universities emphasizing entrepreneurial startups can actually do better by reducing restrictions over intellectual property flows.

Conclusions

When a change triggers an existing institution, the bounded rational agents can transit to a new set of formal and informal institutions, with institutional linkages, complementarities and interdependencies among them. One of major objectives of this paper was to propose a unified, analytical and conceptual framework for understanding the roles of social, political, economic and organizational factors, as well as the nature of their interdependencies, in the process of institutional change.

The identification of powerful institutions able to exert great influence on the university technology transfer efforts it permits to better understand the evolution dynamics of the academic entrepreneurship field. Even if agents may not consciously coordinate their own choices across domains, the presence of institutional complementarities makes them regard an institution in another domain as a parameter and accordingly choose strategies in their own domains, and vice-versa. In such situations, institutions evolving in each of these domains may become interdependent and mutually reinforcing (Aoki, 2001).

The nature of the over-all institutional arrangements can be understood in equilibrium terms, but institutions will change when there is a substantial equilibrium shift. However, gradual changes in equilibrium as a passive response to continual changes in the parameters of the game-form may not immediately be reflected as an institutional change.

According to Aoki's (2001) conceptualization, a change in institution is to be characterized by a quantum shift in equilibrium constellation of agents' strategies such as to generate, as well as induced by, substantive changes in agents' shared behavioral beliefs. Furthermore, dynamic complementarities capture the role of policy in the process of institutional change, which operate gradually and interactively with changes occurring elsewhere.

Indeed, when deviations from the existing patterns of playing occur beyond a certain threshold, hitherto-held individual perceptions about the ways in which the game is not taken for granted any more. Shared behavioral beliefs become de-stabilized, signaling the crisis of institutions.

In the case of the European paradox, Crescenzi, Rodriguez-Pose, and Storper (2007) argue that United States and Europe show marked differences in the institutions and policies governing the invention, development and adoption of new technologies. In contrast, despite the recent and rapid formal institutional-building efforts at EU level, there is yet no analogous Europe-wide system in place (Gregersen and Johnson, 1997; Borras, 2004; Stein, 2004; Lehrer et al., 2009).

The lesson that emerges from the literature is a centrality of the universities in the creation and diffusion of new institutional forms. Not only is university research now evaluated more extensively for its commercial application, universities themselves are increasingly viewed as “engines of economic development” (Feller, 1990; Potts, 2002; Hewitt-Dundas, 2012) and fundamental for new industries (biotechnology – Bagchi-Sen et al., 2001; nanotechnology – Martinez-Fernandez and Leever, 2004).

With the institutional theory lens, a mature field has stable, routinized interactions between participants who have a strong mutual awareness of which organizations occupy given fields and which do not (Scott, 1994, 2001). Universities can offer a powerful support to new agents, such as the technology transfer office, to be the changing force toward a new pattern of interactions. Technology transfer offices can act as institutional entrepreneurs (Jain and George, 2007) and create a whole new system of meaning that ties the functioning of disparate sets of institutions together (DiMaggio, 1988). Assuming the role of champions, they can energize efforts toward collective action and devise strategies for establishing stable sequences of interaction with other organizations to create entirely a new paradigm (Aldrich and Fiol, 1994; Garud, Jain, and Kumaraswamy, 2002).

The integration of technology transfer into the university environment is not straightforward, however. Universities have to enact policies that would concurrently transfer knowledge for the benefit for the public, manage the “business” of technology transfer, and not isolate their faculty. Scientists still question the patenting and licensing of basic research, and the possible ways in which industry would modify the academic research priorities.

The acceptance of technology transfer offices requires the co-mingling of two separate domains. Traditionally, reputation and priority for discovery characterize the aims of the academy, and are reinforced through publication and peer review. In contrast, proprietary knowledge and profit drive industry, reinforced through patenting and legal definitions of inventorship. Scientists need to be helped to navigate these contradictions and make sense of the opportunities and constraints of commercial science. The individual behaviors of scientists are guided by broader cultural understandings, “institutional logics” (DiMaggio and Powell, 1991; Friedland and Alford, 1991; Scott et al., 2000), that define what behaviors are considered appropriate and the space for negotiation of the permissible choices. Thus, an effective technology transfer offices has to explain the legitimacy of the technology commercialization, providing culturally acceptable meanings and institutionalizing the new practices, offering reinforces through feedback mechanisms (Colyvas, 2007).

Institutionalization is both a process and an outcome (Zucker, 1977; Jepperson, 1991).

Formal and informal institutions in the university technology transfer process, in a unified perspective, suggest that the process of institutional change may not necessarily be hierarchically ordered in terms of causation. Despite the fact that policy and legislative actions in the political exchange domain appear to trigger institutional changes in other domains, the process is still characterized by dynamic institutional complementarities in which policy changes, the emergence of new agents and cognitive forces reinforce each other through complementary interactions across domains. However, the challenge of the European economies to increase the capacity to convert scientific breakthroughs and technological achievements into industrial and commercial successes could not be solved only emulating the institutions created in the U.S. to perform the technology transfer process. As the example of the Petri dish reminds us, it's not only a matter of putting together the essential components such as water, carbonium, and heat and mix them all together to create life. In the same way, in the technology transfer environment it's important not only to establish the right institutions to favor its development, but it's more fundamental to organize them coherently and make them playing as an orchestra, each instrument at the right time and with the right intensity.

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THE SIGNALING ROLE OF THE UNIVERSITY COMMERCIALIZATION FUNDS ON VENTURE CAPITAL INVESTMENTS

Abstract

University spinoffs are an important subset of high technology start-up companies. They operate in a context characterized by high information asymmetries that restrict the possibilities for them to obtain financing. The relationships among the main stakeholders involved in the process of creating a university spinoff company, i.e. the academic founders, the university technology transfer office and private investors, are still pretty unclear, with few researches that study the interaction between public grants and private financing for new science-based ventures. Through the database of all the spinoff companies created to exploit University of Michigan-assigned inventions from 1999 to 2010, we analyze how the funds provided through the university technology transfer office influences venture capital follow on-funding, after controlling for the spinoff's technology, the founders' human capital and network's resources. The empirical results, supporting a signaling effect of the commercialization funds provided by the university, suggest a possible effective way in which university spinoffs could overcome the initial funding gap and move forward in their development process.

Introduction

In the last years, the technological opportunities offered by completely new area of research redefined the role that universities have in society. Traditionally the locus of scholarly work, research and teaching, the universities have started to play also a proactive role in the process of technology innovation and its successive transfer to industry and society, supported by the introduction of favorable regulations in the field. For example, the Bayh-Dole Act in the United States allows universities to patent inventions funded by federal money and to retain the royalties that the licensing of these patents can generate.

The process of commercialization of the university researches transforms research discoveries into valuable products and services to market, with the idea that scientific progresses should ultimately benefit the society. To manage efficiently this process, the majority of universities established technology transfer offices (TTOs), semi-independent organizations responsible to recognize the inventions with the strongest potential to make a significant positive impact and

choose the right course of action to support their development. The role of technology transfer offices can be described as “intermediary” between the suppliers of innovations (university scientists) and those who can potentially commercialize them, such as established firms, entrepreneurs, and venture capitalists (Siegel, Veugelers, & Wright, 2007). More specifically, TTOs try to increase the number and quality of the spinoff companies arising from university researches with the provision of a wide range of business support services, the support of intellectual property’s experts and the connection to investors’ networks.

At the moment of the foundation of a spinoff company and in the earlier phases of its development, funding is one of the most relevant difficulties (Chiesa & Piccaluga, 2000; Siegel, Waldman, & Link, 2003; Clarysse, Wright, Lockett, Mustar, & Knockaert, 2007). The “funding gap” has always been a major challenge for high technology companies, and it’s particularly acute in the case of science-based firms, because of high information asymmetries between the inventors and the investors (Lockett, Murray, & Wright, 2002; Hall & Lerner, 2010). As highlighted by Shane (2004: 224): “The initial capital obtained by university spin-offs [...] does not come from private investors, creating a funding gap in the development of university spinoffs”.

In order to reduce the spinoffs’ financial constraints, some universities have created commercialization funds and governmental institutions begin to set up incentives to stimulate technological innovation for small, high-tech, innovative businesses.

The aim of this study it’s to appraise the influence of the commercialization funds provided through the university TTO on the probability to receive venture capital follow-on funding through the database of all the spinoffs created to exploit University of Michigan-assigned inventions from 1999 to 2010 and controlling for other important drivers of VC investments’ decisions, i.e. the spinoff’s technological endowment, the founders’ human capital and network’s resources.

In line with theoretical contributions proposing a signaling role of public funding in reducing the information asymmetry faced by private investors (Chan, 1983; Takalo & Tanayama, 2010; Lerner, 1999) and suggesting a further enriched role for TTOs, the findings point out that venture capitalists perceive the gap funds as a signal about the quality and credibility of the new businesses, and use the information to identify the best spinoffs to finance.

The contribution to the literature are mainly two, with important policy implications in the academic entrepreneurship environment: (i) a study of the effects of the TTO gap funding support, a practice that has become widespread in the universities’ policies, but received little attention in the academic researches; (ii) a new interpretation of the relations between

scientists, technology transfer offices and venture capitalists, the main stakeholders involved in the transfer process of scientific knowledge to society.

The following sections illustrate the problem of asymmetric information and the actors involved in the technology transfer process. Then we review the literature highlighting the studies focused on the relationship between public and private finance in university entrepreneurship to formulate the research's hypotheses. Afterward, we describe the sample, the methods and the variables that have been used to empirically test the hypotheses. Finally, the results of the analyses are illustrated, and their implications discussed.

The funding gap in the technology transfer process

Asymmetry of information in innovation settings

The non-commercial context in which the academic spinoffs emerge typically means that they are not “investor ready”: relative to outside evaluators academic entrepreneurs are privy of the main information about the prospects of their ventures and the commercial value of their inventions, they lack prior history and reputation, face high failure risk, and have concentrated ownership so banks usually are quite reluctant to give them loans. Moreover, early stage venture markets are inefficient and often unable to operate with long-term horizons.

In the innovation setting, the problem of asymmetric information describes the situation in which the inventor has better information about the likelihood of success and the nature of the considered innovation project than potential investors (Hall & Lerner, 2010; Stiglitz & Weiss, 1981). Therefore, the marketplace for financing the development of innovative ideas looks like the “lemons” market modeled by Akerlof (1970): high-quality start-ups face the problem of separating themselves from the rest of the companies in the market.

Spinoff companies suffer heavily for the information asymmetry since usually they account more intangible assets than non-technology based ones and they are characterized by the value of human resources, high firm complexity and high level of uncertainty about their true value. Therefore, university innovations face a large feasibility and funding gap since they are too risky for investors. The level of uncertainty and information asymmetries that obscure evaluations of the technologies limit the raising of external capital, that becomes very expensive or it's entirely precluded (Lerner, 1999).

The literature examines the role of signals as mechanisms that lead to a separating equilibrium among different types of companies. The rationale behind the use of signals is

that if the information asymmetries could be eliminated and the high-quality start-ups could signal themselves efficiently, financial constraints would disappear.

The most studied signaling mechanism is the voluntary disclosure of information about firm's intangible assets and technology's characteristics. Nevertheless the full disclosure of information is not always possible or suggested in innovative environments characterized by the ease of imitation of inventive ideas. The potential cost of revealing information and details of the discoveries to the competitors reduces the signal that innovative firms are willing to send. Thus asymmetric information coupled with the costliness of possible signals imply that firms and inventors find difficult to finance spinoff companies using capital from sources external to the famous three Fs: family, friends and fools.

Following this argument, some innovations without an already wealthy inventor will not be provided to the society merely because the cost of external capital is too high, even when they would pass the test to surpass the breakeven point if funds were available at the right interest rate for the level of risk (Hall & Lerner, 2010).

The Venture Capital financing

The main private financial intermediaries focused on investing in new technology companies are venture capitalists (VC). VC are specialized in raising capital from a variety of institutional and wealthy private investors to invest private equity capitals in high-potential, young companies in the interest of generating a return through a realization event such as the floatation on the public equity market or direct sale of the company.

In exchange for the high risk they take by investing in small and less mature companies, VC usually get significant control over company decisions, in addition to a significant portion of the company's ownership. Unlike most of the other intermediaries, VC actively mold the company and its strategy through participation in strategic decision-making, placement of directors and key executives, and mobilization of other valuable resources via their networks of contacts. This "coach" function for portfolio firms replaces the competence-based argument, i.e. the capabilities of new ventures coincide with founders' skills, in the VC-baked firms: VC investors fundamentally transform the resources and capabilities of portfolio companies and positively affect their growth (Arqué-Castells, 2012; Colombo & Grilli, 2010; Bertoni, Croce & Guerini, 2011).

The presence of a valid venture capital is almost fundamental to feed the development process of the new company (Hall, 2002), but the high uncertainty and significant monitoring costs encountered by venture capitalists in evaluating early stage seed investment in technology and science-based fields results in few VC investments made before a proof of concept (Lockett et

al., 2002). They operate a high selection between the proposals they receive, and in addition, Wright, Lockett, Clarysse, & Binks (2006) claim the existence of a funding bias of VC firms regarding academic spinoffs, created by the low level of maturity and complexity of advanced scientific research and the academic entrepreneurs' lack of commercial skills. The bias seems to be mitigate only when public sector capital is present in the VC firm's own capital and some of the investment managers had previously worked in an academic environment (Knockaert, Wright, Clarysse, & Lockett, 2010).

The Technology Transfer offices

Technology transfer offices (TTOs) are semi-independent organizations instituted with the responsibility to manage the process of technology transfer of the university's inventions. In the last decades, "almost all research universities in the USA and Europe have established technology transfer offices to commercialize their intellectual property" (Siegel et al., 2007: 640) with an isomorphic process that shows academic organizations legitimate themselves replicating the behavior of highest status ones (Baldini et al., 2010)⁴, but often also directly experiment different commercialization methods and learn from the experience.

TTOs are widespread in the practice and have been in the spotlight of research because they are often regarded as the formal gateway between the university and industry. In general, they have the task to identify university's researches that have potential commercial interest and to engage with the inventors, experts, industry and investors to choose the preferred transfer mechanism to take the ideas forward (Shane 2002; Compagno & Pittino, 2006). Between the various commercialization strategies available to universities to valorize their knowledge, i.e. research contracts with industry, licensing of patents to existing companies and spinoff formation, the latter requires the university's more direct involvement.

In fact, an academic spinoff arises when the licensee of a university-assigned invention founds a new company participated by the university itself to economically exploit a university discovery to produce goods or services (Di Gregorio & Shane, 2003). The spinoff phenomenon is relatively new for the majority of the universities (institutions such as MIT and Stanford are the exceptions rather than the rule), but the literature widely assesses the influence of universities' policies and procedures on research commercialization, and especially the crucial role of TTOs, mediated by their resources and personnel experience, in the development of the spinoff companies (DeGroof & Roberts, 2004; Lockett & Wright,

⁴ Baldini *et al.* (2010) affirm that academic organisations legitimate themselves by using mimetic processes, replicating the behaviour of highest status ones. Subsequently, once constrained by a formal regulation/law, they organise themselves and rely on the professionalization of the TTO personnel.

2005; O'Shea, Allen, Chevalier, & Roche, 2005) and in facilitating the technology transfer with the aim of balancing objectives from different stakeholders (e.g., university administration, faculty, and industry) (Siegel et al., 2003; Jensen, Thursby & Thursby, 2003). The majority of TTOs stimulate and support spinoff activity with business support services and resources tailored to young technology and knowledge firms such as intellectual property rights' protection, legal and managerial advice, information about public financial support programs, connections with networks of business angels and venture capitalists (Gübeli & Doloreux, 2005; Clarysse et al., 2007). The best TTOs have cultivated relationships with key VC organizations over time, understanding their investment criteria, so that "when they then reach out to one of these groups with an investment opportunity in an academic spin-out, the investors are likely to consider the new venture seriously" (Lerner 2004: 54).

This support is particularly important for the academic new ventures: at the basis of an academic spinoff there is the initiative of an individual or, most frequently, of a group of researchers, that compared with other entrepreneurs usually shows a lower attitude to risk, lower attention to market and scarce managerial competences. Their involvement is driven by the expectation of generating results that will enhance their academic position rather than an instinctive entrepreneurial attitude (Fini, Grimaldi & Sobrero, 2009). Moreover, if they are not supported in their strategic choices, they tend to search other partners in their technical-scientific environment, choosing to assign in this way a primary role to research and little attention to the commercial side of the new venture (Colombo & Grilli, 2005).

Theoretical background

In order to reduce the financial constraints for technology transfer activities, public research organizations began to set up incentives to profit from the commercialization of technological potential and increasingly create funds to support market researches, commercial assessments and proofs of concept to compensate for the lack of private investments in scientific innovations (Wright et al., 2006; Clarysse et al., 2007).

From empirical observations, Shane and Stuart (2002) suggest that the financial involvement of the parent organization may hint the inability to procure other forms of capital investment. Moray and Clarysse (2005), describing the evolution of science-based entrepreneurial firms at IMEC, Belgium, find that organizational changes in technology transfer policies, also in the funding process, are mirrored in the spinoff companies founded in different periods. They report: "IMEC learnt that the seed phase is not interesting for venture capital firms and tried to tackle this by setting up an Incubation Fund dedicated to invest in pre-seed and seed

capital” (Moray & Clarysse, 2005: 1023). Shane (2004: 228) comes to a similar observation: “In some cases, the government serves as a catalyst for private sector financing by paying for the initial test that proves the value of a technology and so motivates private investors to make subsequent investments”. Gulbranson and Audretsch (2008) report the example of two programs centered in engineering schools, the MIT Deshpande Center for Technological Innovation and the UCSD von Liebig Center that helped advance 26 startups that have raised a total of \$160 million in outside investments, after granting less than \$10 million to projects. Reasoning on R&D subsidies and financial constraints, Takalo and Tanayama (2010) develop a theoretical framework that supports a complementary relationship between public and private financing: the screening activities typically embedded into R&D subsidy policies can have a role of their own in reducing financial constraints playing a certification role. The signal of quality associated with the subsidy reduces adverse selection problems faced by financiers and contributes to the removal of the financing constraints of technology-based entrepreneurial firms. Samila and Soreson (2010) find a positive relationship between government research grants to universities and research institutes and the rates of firm formation in a region, with this relation becoming more pronounced as the supply of venture capital in that region increases. Lerner (1999), who studies the Small Business Innovation Research (SBIR) program, the largest public subsidization of small high-technology firms, finds that SBIR awardees are significantly more likely to receive venture financing, especially firms based in US ZIP codes with substantial venture capital activity (California and Massachusetts). Consistently with perspectives that emphasize the importance of an innovation ecosystem, these findings point to a strong interaction between private financial intermediation and public research funding in promoting entrepreneurship and innovation. So, on one side the literature has presented empirical studies on the effects of the TTO commercialization funds, on the other, it has proved the signaling effects of R&D subsidies. Thus, we conjecture a positive influence of the commercialization funds provided through the university TTO on the likelihood that the spinoffs attract venture capital financing and the amount of investments received.

The rationale behind this assumption is that the university TTO suffer less than the VCs from information asymmetry since it has a direct relationship with the scientists and their university department of affiliation, build upon a network of informal relationships. In fact, as demonstrated by Johansson, Jacob, & Hellstrom (2005), the network relations between the spinoffs and universities are based on small number of strong ties, with a high degree of trust and informality. Elfring and Hulsink (2003) affirm that the strong ties are important for

ventures pursuing radical innovations as they enable “trusted” feedback and exchange of tacit knowledge on the nature of the opportunity.

It is reasonable to hypothesize that, when the TTO’s financial promotion follows a selection and assessment stage, the provision of gap funds and the amount of gap funding obtained by the invention can play a fundamental signaling role to direct the venture capitalists’ decisions toward the qualitatively better spinoffs. In this way, it can close the funding gap between basic research and private sector investments and helps to overcome the difficulties faced in trying to fund proof of concept and prototype development.

Hypothesis 1: For spinoff companies, receiving TTO gap funding increases the probability to receive VC financing.

Hypothesis 2: For spinoff companies, the amount of TTO gap funding received increases the amount of VC financing received.

Methodology

Sample

The data set we analyzed includes the population of 112 spinoff firms founded to exploit inventions assigned to the University of Michigan between 1999 and 2010. Like many other U.S. universities from the Bayh–Dole legislation, the University of Michigan takes title to commercialize useful inventions that are developed by faculty, staff, or students and that emerge from work making material use of university’s resources (e.g., laboratory facilities). Of course, there is no presumption of a random sample here, but the sample does not suffer from a survivorship bias: all the spinoff firms with a University of Michigan license are represented in the sample.

The population of spinoff companies was identified from the U-M Tech Transfer’s database that collects data about the spinoffs and the gap funds provided them. Data about the licensed patents has been retrieved by the USPTO database.

The University of Michigan Tech Transfer is a successful case of technology transfer in an average federal state, even problematic if we consider the crisis that Detroit faced in the last thirty years. Despite the environment is not as favorable as the Route 128 or the Silicon Valley, the University of Michigan is positioned well within the top ten universities for license agreements and spinoff companies created every year (AUTM data).

The small number of strong ties, with a high degree of trust and informality described by Johansson et al. (2005), is found in the U-M Tech Transfer’s routine.

When scientists discover a new process, instrument or material compound, the invention is disclosed before the publication to the U-M Tech Transfer and to the sponsor partners, if present, with the fulfillment from the scientists of an Invention Report Form. It's a document protected by a non-disclosure agreement, with a detailed description of the discovery and a suggestion about companies possibly interested at the invention.

It follows an evaluation phase, where the personnel of the TTO realizes market studies to assess the feasibility of an intellectual property protection and the commercialization potential of the discovery in comparison with the technologies already present on the market. The criteria adopted related to the innovativeness, the exclusivity, the dimension and growth of the technology field, the amount of investment required and the timing of the development.

If the invention is patentable and it has an economic potential, then a patent request is presented with the collaboration of the scientists and lawyers specialized in patent issues. At this point, the scientists and the TTO evaluate if licensing the patent to an established firm or to undertake path to create an academic spinoff.

Licensing to an existing company is the most common solution (90% of the cases), while the creation of a spinoff company is chosen generally when there are the potential development of a range of products from the same technology, an interesting target market or potential revenues able to sustain a new company.

A team of specialized consultants and mentors (named Michigan Venture Center) supports the business creation with operational and strategic advise on the legal foundation of the company, the writing of the business plan and the research of financing opportunities, public or private. They also evaluate with the inventors their willingness to participate in the project, in terms of time, effort, and flexibility. The inventors can assume different roles, from consultancy, to a formal scientific support in the advisory board, or also a direct participation in the management and ownership of the company. The office usually suggest the scientists to complement their knowledge with subjects with economic-managerial experience.

We personally followed a series of meetings with a possible future spinoff and the subjects discussed could be mainly grouped in five categories: business planning (29%), funding (27%), product development (22%), academic work (12%) and company formation (10%)⁵.

In general, the approach chosen by the U-M Tech Transfer can be recognized in the "Comprehensive support and selectivity" academic "spin-off policy" (Degroof & Roberts, 2004): (i) a proactive opportunity search stimulating disclosures, (ii) a very selective-specific

⁵ Between parentheses we report the percentage of the meetings' time devoted to the different topics.

criteria for transfer of technology via spin-off strategy versus licensing, (iii) strong intellectual property rights' protection, (iv) market research-product development with help of outside consultants to evaluate the start-up feasibility, (v) support networks with financial partners and consideration with the inventors of their possible role in the spinoff.

Dependent variables

VC follow-on funding is measured alternatively by a binary variable coded 1 if the spinoff has received any VC support and by the hyperbolic sine transformation of the amount of venture capital obtained by the spinoff firm in Dollars.

$$IHS(y_i) = \log(y_i + (y_i^2 + 1)^{1/2})$$

We compute the inverse hyperbolic sine transformation (IHS) of the VC funds because IHS is an alternative to logarithm transformation when the distribution of the variables is skewed and some of variable take on zero or negative values (Burbridge, Magee, & Robb, 1988). The high presence of zero in the VC financing distribution suggests that IHS transformation should be preferred to the transformation $\log(y+1)$ to avoid alteration of the regression's beta. Financing provided by business angels, supplier/customer investments, bank and other third party's loan (usually family and friends) are excluded.

The period in which spinoffs in the sample received VC financing goes from the foundation of the spinoff to three year after, with an average of one year and a half after the foundation.

Main explanatory independent variable: TTO gap funds

The variable "TTO gap funds" describes the pool of resources within the university for funding the early commercialization activities of technologies with a strong commercial potential. Projects suitable for gap funding typically have progressed on a commercial path beyond the point where traditional research funding sources are appropriate but have not yet reached the point where they are fully commercially viable.

TTO gap funding is measured alternatively by a binary variable coded 1 if the spinoff has received any TTO support and by the hyperbolic sine transformation of the amount of funds obtained by the spinoff firm in Dollars.

$$IHS(x_i) = \log(x_i + (x_i^2 + 1)^{1/2})$$

The rationale for the use of the hyperbolic sine transformation (IHS) is the same as described above for venture capital financing.

Specifically, TTO funds include:

- funds provided by MUCI and MIIE, and matched by the University of Michigan,

- federal funding resources, i.e. SBIR and STTR grants, for which the TTO provides support in the application procedure.

MUCI (Michigan Universities Commercialization Initiative) is a collaboration designed to complement and enhance the technology transfer at Michigan academic and research institutions by supporting commercialization of intellectual property. The MUCI Challenge Fund provides pre-seed investment stage money to help institutions to test and validate the market need for an interesting technology.

MIIE (Michigan Initiative for Innovation and Entrepreneurship) is a consortium of all fifteen Michigan Public Universities acting together strategically to leverage university assets to enhance the State's economic competitiveness and stimulate growth. The consortium supports individual universities and encourages regional collaboration between universities, foundations, economic development organizations, government agencies, and private enterprise. Working with a grant from the C.S. Mott Foundation, MIIE accepts proposals to three funds: Technology Commercialization, Industry Engagement, Talent Retention & Entrepreneurship Education.

MUCI and MIIE applications must come from its member research institutions' TTOs and require the universities to match the requested funds. In the application the funds required must be justified with the following specifications: market research, commercial assessment, proof of concept, translational and user studies, IP enhancement, prototype development or testing, feasibility studies for scale-up and/or business plan preparation.

The review committee is composed by research administrators and tech transfer experts from various Michigan public universities as well as representatives from industry and the venture capital community that are asked to evaluate for each proposal the following aspects: clear competitive advantage of technology, the market need, the commercialization plan, the likelihood of a new product/ process within 3 to 7 years, validation meaning the apparent entrepreneurial effort and outside interest and the applicability, i.e. if the proposal is appropriate for the intent of the fund.

Other sources of funding aimed to further develop a technology, called translation research programs, were not considered in this research.

SBIR (Small Business Innovation Research) and STTR (Small Business Technology Transfer) are programs administered by the U.S. Small Business Administration Office of Technology to ensure that the small, high-tech, innovative businesses are a significant part of the federal government's research and development efforts. SBIR is a competitive program that encourages small business to explore their technological potential and provides the

incentive to profit from its commercialization. Following submission of proposals, agencies make SBIR awards based on small business qualification, degree of innovation, technical merit, and future market potential. Small businesses that receive awards then begin a three-phase program:

- Phase I is the startup phase. Awards of up to \$100,000 for approximately 6 months support exploration of the technical merit or feasibility of an idea or technology.
- Phase II awards of up to \$750,000, for as many as 2 years, expand Phase I results. During this time, the R&D work is performed and the developer evaluates commercialization potential. Only Phase I award winners are considered for Phase II.
- Phase III is the period during which Phase II innovation moves from the laboratory into the marketplace. No SBIR funds support this phase.

In the sample, SBIR and STTR funds account for 54,02% of the total commercialization funds. We consider them together with the MUCI and MIIE funds since the application procedure has been strongly supported by the U-M Tech Transfer specialists, as it has emerged from the meetings we followed.

Spinoffs in the sample received TTO funds from three years before the spinoff's foundation to one year after, with the higher frequency at one year before.

Other explanatory and control variables

Various aspects of the new ventures impact the likelihood that spinoff firms would obtain financing. Among the most studied there are factors related to the technology (such as the innovativeness of the patent), the human capital of the founders and the network of relations that the founders could exploit to obtain support for the start-up (Shane & Stuart, 2002; Heirman & Clarysse, 2004; Chiesa & Piccaluga, 2000).

Technology endowment

Technology endowment for the spinoff companies is strongly related with the patent/patents they license from the university. Shane and Stuart (2002) study on the performance of 134 spin-offs from MIT from 1980 to 1996 shows that those spinoffs with more effective patents and richer social ties with third-parties were more likely to obtain financing.

Previous work using the measures of patent basicness have demonstrated their validity as measure of patent importance in terms of impact on later innovation in a field (Henderson, Jaffe, & Trajtenberg, 1998; Hall, Jaffe, & Trajtenberg, 2001). Basicness of a patent refers to the fundamental features of innovations such as originality, closeness to science, generality of research outcomes and it's calculated as suggest by Henderson et al. (1998):

$$GENERAL_i = 1 - \sum_{k=1}^{N_i} \left(\frac{NCITING_{ik}}{NCITING_i} \right)^2$$

$$ORIGINAL_i = 1 - \sum_{k=1}^{N_i} \left(\frac{NCITED_{ik}}{NCITED_i} \right)^2$$

$$SCIENCE_i = \frac{NPCITES_i}{NPCITES_i + NCITED_i}$$

where NCITING is the number of patents citing the originating patent, NCITED is the number of patents cited by the originating patent and NPCITES is the number of non-patent sources cited by the originating patent. These characteristics discriminate well between less and more basic innovations.

Generality will be high if subsequent patents that cite a patent belong to a wide range of fields, whereas if most citations are concentrated in a few fields it will be low (close to zero). Originality, instead, will be high if a patent cites previous patents in a wide range of fields, whereas citing patents that belong to a narrow set of technologies would render a low score.

These measures tend to be positively correlated with the number of citations made (for originality) or received (for generality): in fact highly cited patents tend to have higher generality scores, and patents that make lots of citations would display on average higher originality because of a built-in tendency to cover more patent classes where there are more citations (Hall et al., 2001).

Human capital

The human capital of the founding team can influence VC decisions (Colombo & Grilli, 2010) and the venture growth (Baum & Locke, 2004; Shane & Stuart, 2002).

Human capital is represented by the knowledge and capabilities that an individual owns and that are developed through education and experience. A recent study realized by Colombo and Grilli (2010) on new technology-based firms claims that founders' human capital has both a direct positive effect on firm growth and an indirect one, mediated by the attracting of VC. The variables are the number of founders (n_founders), the education at university level (edu) and the working experience in the field of the spinoff (work) of the members of the founding team. The data report an average number of founders of 2.34, the average education at university level of the founders is 8.92 years circa and the average work experience is 17.25 years circa.

Table 1 - Definition of study variables and descriptive statistics.

Variable	Description	Mean	SD	Min	Max
vc_d	Dummy=1 for spin-off firms that obtained venture capital.	.46	.50	0	1
vc	Venture capital obtained by the spin-off firm in Dollars.	6.59 M	15.4 M	0	84.0 M
GAP FUNDS:					
tto_d	Dummy=1 for spin-off firms that received the technology transfer office funding.	.66	.48	0	1
tto	TTO funds obtained by the spinoff firm in Dollars.	0.76 M	1.14 M	0	4.75 M
Scientific endowment:					
general	Herfindahl index on technological classes of citing patents	.32	.30	0	.9
original	Herfindahl index on technological classes of cited patents	.50	.28	0	1
science	Measure of the scientific base outside the patents system	.54	.35	0	1
Human capital:					
n_founders	Numbers of founders.	2.34	1.23	1	8
edu	Average number of years of education of founders at university level.	8.92	1.79	4	13
work	Average number of years of work experience of founders before firm's foundations.	17.25	9.01	3	40
Network resources:					
vcexp	Dummy=1 if one of the founders had relations with VC before founding the spin-off	.18	.38	0	1
startupexp	Dummy=1 if one of the founders starts a business before the spin-off	.39	.49	0	1
Age and field controls:					
age	Number of years from spin-off firm's foundation.	5.75	3.36	1	12
dum_9901	Dummy=1 for companies founded in 1999, 2000, 2001.	.21	.41	0	1
dum_0204	Dummy=1 for companies founded in 2002, 2003, 2004.	.23	.42	0	1
dum_0507	Dummy=1 for companies founded in 2005, 2006, 2007.	.21	.41	0	1
dum_0810	Dummy=1 for companies founded in 2008, 2009, 2010.	.35	.48	0	1
Med	Dummy=1 for companies classified in the groups 283 - "Drugs" and 384 - "Surgical, medical, and dental instruments and supplies" with the US SIC Code.	.22	.42	0	1
Software	Dummy=1 for companies classified in the group 737 - "Computer programming, data processing, and other computer related" with the US SIC Code.	.17	.38	0	1
R&D	Dummy=1 for companies classified in the group 873 - "Research, development and testing services" with the US SIC Code.	.35	.48	0	1

Network resources

Mosey and Wright (2007) highlight that the entrepreneurs who experienced the creation of a start-up before can count on a wide and profitable network of relationships and show the ability to easily increase the relational capital to obtain new resources. Thus, companies founded by individuals with previous VC or start-up experience may have an advantage relative to organizations created by first-time entrepreneurs. Grandi and Grimaldi (2003) consider the intention of the founding team to set up relations with external agents as a “predictor of success”.

We construct two binary variables, VCs’ experience (vcexp) and start-up experience (startupexp), coded 1 if at least one member of the founding team had previous relationships with a VC firm or had launched a new company (Knockaert et al., 2010).

The **age and industry control variables** in the models are related with the year in which the spin-off was founded (dum_9901, dum_0204, dum_0507, dum_0810). The age variable shows that spinoff companies in the sample are relatively young (5.75 years).

We control for the industry considering the Group in the US SIC Code of the company.

The entire sample comes from the University of Michigan-assigned inventions: this allows us to rely on parsimonious models and do not control for factors related to the university (IP protection, incentive system, culture, status, policy and experience), neither for environment external factors (availability of VC, industrial research support, state-level economic growth, government policies) (Rothaermel, Agung, & Jiang, 2007). Also the reputation effect, i.e. the fact of being spun off from a credible university that guarantee for the quality of the knowledge-based companies, does apply to the whole sample (Di Gregorio & Shane, 2003).

Models

To test the first hypothesis, we construct three logit models since the dependent variable is coded as a dichotomous variable and the c.d.f. is similar to a logistic distribution.

The second hypothesis instead is tested through tobit models. Tobit models are appropriate when the dependent variable y_i of a linear regression is equal to the latent and unobservable variable y_i^* whenever the latent variable is above zero and zero otherwise. The zeros are left censored observations of the dependent variable.

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

Tobit models are the appropriate models to analyze the sample because the variables are observed only when they assume a value greater than zero (corresponding to the cases in which VCs have decided to finance the spinoff, see table below) and zero otherwise.

	vc_d		Total
	0	1	
tto_d	0	1	
0	32	7	39
1	28	45	73
Total	60	52	112

Indeed, the model cannot be estimated by ordinary least square because of the relevant presence of observations equal to zero (corresponding to all the spinoffs that didn't receive VC follow-up funding).

The variance is not homogeneous along the distribution (heteroskedasticity), so we preferred to calculate the robust standard errors for all the models.

The logit and tobit models in which both the variables related to the TTO gap fund are inserted (not reported) see both variables positive but not significant, this is caused most probably to the high correlation (0.96) between them.

All statistical calculations are performed with the software package Stata/IC 12.

Results and discussion

The descriptive statistics show that 46% of the spinoffs received VC financing and VC-follow on finance on average provided \$ 6.59 millions. The high percentage of VC baked firms between U-M spin-offs already suggests an alteration in the VC financing process: in fact usually only 2% of the companies that apply for VC financing are able to obtain it.

TTO gap funds have been provided to a high percentage of the spinoff (66%), with an average amount of \$ 760000 circa and a skewed distribution, with the median equal to \$ 252000.

The correlations between the variables analyzed are provided in Table 2. Correlations are high and significant (from 0.40 to 0.45) with the TTO gap funding variables, and the previous experience in dealing with VC of at least one of the founders (0.27). In order to examine multicollinearity, we calculated the variance inflation factor (VIF). VIFs are between 1.12 and 1.31, which is below the rule-of-thumb cutoff of 5, thus issues of multicollinearity do not seem to prompt concern.

Table 2 - Correlations of study variables

	1	2	3	4	5	6	7	8	9	10	11	12
1.vc_d	-											
2.vc_ihs	.96	-										
3.tto_d	.45	.40	-									
4.tto_ihs	.45	.41	.96	-								
5.general	-.04	-.01	.13	.16	-							
6.original	.13	.16	.09	.12	-.02	-						
7.science	.17	.17	.01	.03	-.04	-.06	-					
8.n_found	.17	.17	.13	.14	-.02	.13	-.19	-				
9.edu	-.01	-.02	.22	.23	-.17	-.02	.07	-.06	-			
10.work	-.04	-.01	-.03	-.01	.03	.13	.04	-.22	-.04	-		
11.vcexp	.27	.27	.12	.13	-.13	-.01	.19	.22	-.11	-.02	-	
12.startup	.17	.13	.12	.15	-.13	-.02	.22	.18	-.03	-.11	.32	-
13.age	.11	.16	.07	.06	.25	-.07	.02	-.12	.04	.30	-.11	-.19

Table 3 illustrated the results of the logit model estimating the factors that affect the likelihood to receive VC financing and the results of the tobit model estimating the factors that affect the amount of VC obtained. We can observe that there is little difference between the models, in fact the logit models could be considered a particular case of the tobit ones and they convey the same information for the part related to the zero values of the dependent variable. To test for collinearity violations, variance inflation factors were computed for each variable (not shown), all of which were under 1.47.

Table 3 - The determinants of venture capitalists' decision to finance spinoffs and the amount of finance invested.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Logit^a	Logit^a	Logit^a	Tobit	Tobit	Tobit
VARIABLES	vc_d	vc_d	vc_d	vc_ihs	vc_ihs	vc_ihs
Constant				-6.06 (6.03)	-6.66 (6.98)	-7.99 (8.16)
dum_9901	0.37** (0.13)	0.37* (0.16)	0.38* (0.16)	12.50** (4.03)	10.46** (3.87)	11.25** (3.87)
dum_0204	-0.12 (0.17)	-0.16 (0.17)	-0.15 (0.17)	-1.12 (4.25)	-1.82 (3.93)	-1.24 (3.93)
dum_0507	-0.08 (0.15)	-0.07 (0.16)	-0.05 (0.15)	-2.33 (3.79)	-2.90 (3.14)	-2.03 (3.19)
med	0.29 [†] (0.16)	0.23 (0.18)	0.26 (0.18)	6.74 [†] (4.02)	3.74 (3.44)	4.41 (3.54)
software	-0.19 (0.15)	-0.02 (0.11)	-0.01 (0.10)	-6.43 (4.94)	-1.76 (4.73)	-1.57 (4.87)
R&D	-0.02 (0.13)	-0.05 (0.15)	-0.03 (0.15)	-0.91 (3.76)	-1.17 (3.39)	-0.93 (3.46)
Scientific endowment: general	-0.18 (0.20)	-0.34 (0.24)	-0.34 (0.24)	-7.25 (4.94)	-9.03 (4.57)	-8.86 (4.69)
original	0.45* (0.21)	0.42 [†] (0.21)	0.46* (0.22)	10.46* (3.89)	9.73* (3.86)	10.81* (3.86)
science	0.31 [†] (0.16)	0.46* (0.20)	0.47* (0.20)	7.62* (3.63)	8.02* (3.75)	8.65* (3.74)
Human capital: n_founders	0.08 (0.06)	0.07 (0.05)	0.07 (0.05)	1.44 (1.16)	0.95 (0.95)	0.98 (0.96)
edu	-0.03 (0.03)	-0.07 (0.04)	-0.07 (0.04)	-0.95 (0.72)	-1.53* (0.71)	-1.53* (0.73)
work	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.06 (0.06)	-0.10 (0.16)	-0.09 (0.16)
Network resources: vcexp	0.34* (0.15)	0.30* (0.15)	0.31* (0.15)	8.70** (3.22)	7.04* (3.00)	7.33* (2.99)
startupexp	0.13 (0.11)	0.13 (0.13)	0.14 (0.13)	2.80 (3.01)	1.33 (2.74)	1.52 (2.77)
Gap funding: tto_ihs		0.05** (0.01)			1.07** (0.26)	
tto_d			0.51** (0.11)			13.12** (3.64)
Wald $\chi^2(15)$	22.20 [†]	42.16**	39.33**			
F(15,97)				4.55**	8.07**	7.90**
Pseudo R ²	0.24	0.35	0.34	0.07	0.11	0.11
Observations	112	112	112	112	112	112

Note. Robust standard errors are in parenthesis. ^a Marginal effects coefficients are shown.

[†] p < .10

* p < .05

** p < .01

Between the variables related to the characteristic of the patent, originality and science have a positive and significant effect, suggesting the importance of the novelty of the innovation. We think that the importance of the scientific background in comparison with the citations to other patents is related to the university environment, in which star scientists tend to publish more than to patent and consequently referring to their and their peers' scientific articles.

The importance of patenting activities in determining greater funding from VC funds has been found also in Cao and Hsu (2011) and Baum and Silverman (2004).

The characteristics of the human capital seem not to affect the VC's decision, we find a even negative significant effect in models 5 and 6, a result similar to the one of Colombo and Grilli (2010). In the spinoff context, the results could be explained by the homogeneity of the human capital: in our sample in fact 75% of the spinoffs can count on more than 8 years of average education of the founders, and 10 years of average work experience. Also in the description of the "average" human capital of a spinoff firm Chiesa and Piccaluga (2000) find that the majority of academic spinoffs are founded by a group of scientists highly homogenous regarding its human capital.

The positive and significant impact of the previous contacts with VCs underlines the importance of the founders' network capital to obtain the VCs' trust. The experience to have found a startup before, instead, is positive but not significant. The results are not surprising: social ties with VCs have been identified as an important precursor to organizational resource attainment and performance (Hsu, 2004).

The models support both the hypotheses conjecturing a positive effect of TTO gap funds on the probability to receive VC financing and on the amount of TTO gap funding received. In fact, both the coefficient of the binary variable related to TTO funds and the coefficient of the amount received through the TTO are positive and significant on the likelihood to receive VC financing (respectively, model 2: $\beta = 0.05$, $p < .00$, model 3: $\beta = 0.51$, $p < .00$) and on the amounts invested by VC (respectively, model 5: $\beta = 1.07$, $p < .00$, model 6: $\beta = 13.12$, $p < .00$), after controlling for the spinoff's technology, the founders' human capital and network's resources.

Conclusions

Over the past thirty years, there has been a growing interest towards academic entrepreneurship that is become an increasingly accepted mode of exploiting potentially valuable scientific discoveries.

As the Bayh–Dole legislation came into effect, the independence of the universities allowed the creation of technology transfer offices with different systems, personnel and mechanisms of technology transfer. “Bridging institutions” between university, industry and investors, the TTOs have a crucial role to create a common knowledge and a common language to reinforce and unify these different worlds through the innovation created by the scientific research.

Although universities’ efforts to commercialize their researches, TTOs discovered soon that early stage venture markets are inefficient and most university innovations are too risky for investors; therefore, they face a large feasibility and funding gap. The growing disconnection between VCs, whose current business model requires them to invest large amounts, and a large class of spinoffs that need a couple hundred thousand dollars to prove their concepts, accentuates the problem. Thus, to compensate the funding gap, we observed the emergence of different forms of public support to spinoff companies such as public venture funds, commercialization grant programs, seed capital funds participated by the governments, universities and other foundations.

The public efforts to improve the spinoffs’ probability of success are justified by the belief that spinoffs generate positive externalities: investments in companies developing sophisticated technologies and research-derived products are demonstrated to have positive spillovers that benefit other firms or society as a whole, but firms making these investments are unlikely to capture the entire surplus.

In this research, we studied the influence of the commercialization funds provided through the university technology transfer office on venture capital follow-on funding, using the database of spinoff companies created to exploit University of Michigan-assigned inventions.

The University of Michigan’s TTO chose a selectivity-support strategy to business formation, sustaining spinoffs with intellectual property rights’ protection services, legal and managerial advice, mentors, connections with venture capitalists and networking events. Furthermore, they provide funds through an inter-university collaboration and assistance in applying to government programs supporting small, high-tech, innovative businesses. Since this financial promotion is not blind but it follows a selection and assessment stage carried on by the TTO business specialists and it’s based on informal relationships permeated of trust and conventions, the TTO has become a trusted intermediary for VC and play what Lerner (2004) defined as “an honest broker” role.

Indeed, the findings illustrate that among all the spinoffs, the ones that received also TTO funds have more probability of receive private funding. The theoretical hypothesis of a signaling effect of the gap funds about new businesses’ quality is accepted, implying the idea

that VC firms consider the spinoff that received commercialization funds through the technology transfer office as the best spinoff companies to finance. The proposal is quite interesting because it suggests a further scope for the public financial support that goes beyond the immediate generation of returns that cover the cost of investment. The results on VC financing clearly show that after TTOs finance the seed phase of the spinoffs with the limited investment necessary to take them from the opportunity framing phase to the pre-organization phase, then spinoffs are in a better position to obtain VC investments and proceed toward the sustainable returns phase. So although VCs are supposed to invest in younger and risky companies in comparison to private equity funds, rarely they decide to finance the very early stage seed investment, preferring instead to enter in the new venture in the first round of finance. A TTO gap fund, correctly managed, could have a significant effect on the creation of a spinoff that becomes successful and one that merely survives without receiving VC financing and/or becoming profitable.

We recognize that this is a preliminary result, with the main limitation regarding the smallness and specificity of our sample; we acknowledge that considering only the spinoffs created by a single university limits the generalizability of the research. However, considering a sole university allows us to rely on parsimonious models, fixing the factors related to the external environment (industry support, propensity to entrepreneurship, availability of venture capital) and about the TTO (experience of the personnel, culture and resources). The scope of the research is to suggest, more than to scientifically prove, a way to understand a process populated by many stakeholders and still pretty unclear.

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UNIVERSITY COMMERCIALIZATION FUNDS AND THE IMPACT ON SPINOFFS' GROWTH

Abstract

University technology transfer offices nurture the development of spinoff companies arising from university's researches with business support services, resources and funding tailored to young technology firms. The literature studies the impact of this support on spinoffs' quality and quantity, while it has been difficult to assess the contribution to spinoffs' consequent growth. Through the database of all 112 spinoff companies created to exploit University of Michigan-assigned inventions from 1999 to 2010, I analyze how the funding support provided through the university technology transfer office (TTO gap funding) influences spinoffs' sales growth. The results suggest an indirect impact, through the mediating effect of VC financing, on spinoffs' sales growth.

Introduction

Policy-makers have become increasingly interested in the role universities can play in economic development. The term "entrepreneurial" oriented university has been coined by Etzkowitz (1998) to describe the tendency of universities to go beyond the provision of graduates and research and, instead, play a key role for regional economic development.

Since the Bayh-Dole Act in 1980, performers of federally funded research received a blanket permission to file for patents on the results of such research and to grant licenses for these patents, including exclusive licenses, to other parties, and encouraged universities to create a semi-independent organization to market and manage their patentable inventions. Consequently, almost all research universities in the USA and Europe have established their technology transfer offices (TTOs) to commercialize their intellectual property (Siegel, Veugelers, & Wright, 2007). As the emphasis on a knowledge-based economy becomes increasingly important, universities play an essential role in the development of the national economy.

Technology transfer offices are responsible for identifying researches that have potential commercial interest and for managing the process from the invention disclosures, to the evaluation of the technology innovativeness, the protection's possibility, and ultimately to the choice of the preferred transfer mechanisms. The three principal methods utilized to

commercialize the university knowledge are research contracts with industry, licensing of patents to existing companies and spinoffs formation.

Among the different channels, licensing is the traditional way to transfer the technology from the university to the private sector: the university is able to capitalize on the technology and the academic scientist is able to pursue her research without having to commit large amounts of time to commercial matters (Lockett and Wright 2005). The main disadvantage is that universities may not be able to capture the full value of their technology through a licensing arrangement and, therefore, in some cases prefer a more direct involvement in the commercialization of new technologies spinning-off firms based on the university inventions. Therefore, the practice of founding a spinoff company that embodies a technology developed inside the university has raised constantly in the academic entrepreneurship environment, driven by the perception that ownership of equity in a university spinoff increases the potential upside gain for university in comparison with licensing (Bray and Lee 2000) and it can develop a third stream of financing (Mustar and Wright 2010).

The broad scope of TTOs to assure that university inventions will ultimately benefits the society raised a debate to create metrics to assess the impact of TTOs' activity that go beyond the number of license agreements, license revenues and number of spinoffs created (i.e. AUTM's Proposal for the Institutional Economic Engagement Index). In particular regarding spinoff companies, scholars and practitioners have underlined that the focus of universities and policy-makers should be on the commercial viability and the wider and longer-term impact of these new ventures (Lambert 2003, Bozeman 2000). While it has long been accepted that the university can be an abundant source of new ideas that eventually may transfer into the market, there has been a debate about the actual paths of such transfer and its direct economic significance (Salter & Martin 2001, Mowery et al 2001, Nelson et al 2001; Cohen et al 2002, Sampat et al 2003).

With this scope, in this research I analyze how the funding support provided through the University of Michigan's technology transfer office (address as TTO gap funds in the paper) influences spinoffs' sales growth. I choose the University of Michigan because the U-M Tech Transfer is an interesting case of a successful technology transfer in an average U.S. federal state, which experienced the crisis of the automotive sector, far from the exceptionally favorable conditions of the Route 128 (Massachusetts Institute of Technology) or the Silicon Valley (University of Stanford and UC Berkley). Despite the state's overall economic conditions, the University of Michigan is positioned well within the top ten universities regarding the number of license agreements and spinoff companies created every year

(AUTM data), its total spinoffs' survival rate is 88,6%, and the spinoffs created in the last eleven years accounts for \$247 million annually in sales revenues and 1784 employees.

The results show that while in the simple regression the TTO gap fund seems to have a positive but not significant impact on spinoffs' growth, in reality it has an indirect effect through venture capital follow-on investments, confirming the researches claiming a preponderant role of early stage capital in the new ventures' development, as well as by programs that enable innovators, entrepreneurs, and investors to connect with each other (Wright et al. 2006, Colombo and Grilli 2010).

The following section begins with a brief review of the literature discussing the role of technology transfer offices. Afterward, I describe the sample, the methods and the variables that have been used to test the effects of university technology transfer's funding. Finally, the results of the analyses are illustrated, and their implications discussed.

The University technology transfer office support

The commercialization of knowledge resulting from university research is a process of technology transfer by which research discoveries and inventions are transformed into valuable products and services that benefit society (European Commission, 2007). Technology transfer offices facilitate this process through licensing to existing firms with appropriate resources and expertise to move the discoveries into market or start-up companies. The activities of TTOs have important economic and policy implications, since licensing agreements and university-based spinoffs can result in additional revenue for the university, employment opportunities for university-based researchers, and technological spillovers stimulating additional R&D investment and job creation (Siegel et al. 2007).

University spinoff originates when the licensee of a university-assigned invention creates a new company to exploit it. Numerous studies demonstrate the important role that academic spinoffs can play as an engine in supporting economic and technological growth. In addition, it has been underlined that spinoff firms outperform the other ventures according to the education of the workforce, the adoption of innovative information and communication technologies and the ability to take advantage of the scientific and technical services provided by research organizations (Fontes 2005, DeGroof and Roberts 2004). They create the opportunity for a network of innovative businesses connected with the parent university through collaboration, research contract and personal interaction of the star scientists. Formal and informal connections enhance the entrepreneur role model among students, other than provide the chance for interesting thesis and stage (Compagno and Pittino, 2006).

Both micro and macro-level factors influence the decision to form a university spinoff.

At the micro-level researches outline the role of technology characteristics (Rothaermel et al. 2007; Shane 2004) and academic entrepreneurs, in particular their lower attitude to risk, lower attention to market and their attitude to search other partners in their technical-scientific environment (Colombo & Grilli, 2005).

While at the macro-level the role of university infrastructures and policies, venture capital availability and the influence of the economic regional development have been pointed out (Di Gregorio and Shane 2003; Clarysse et al. 2005; Lockett et al. 2005, Fini et al. 2009). The transfer of the research discoveries and their valorisation require the overcoming of legal, organizational, cultural and financial barriers.

So the creation of spinoff firms is not straightforward, but it's a process that needs to be sustained and stimulated, in particular because it could have positive externalities in the socio-economic environment of a country.

TTOs encourage and support spinoff activity offering appropriate and useful assistance, business support services and resources tailored to young technology and knowledge firms such as intellectual property rights' protection, legal and managerial advice, information about public financial support programs for new firms, connections with networks of business angels and venture capitalists (Gübeli and Doloruex, 2005).

The role of TTOs can be described as "intermediary" between the suppliers of innovations, university scientists, and those who can potentially commercialize them, i.e. established firms, entrepreneurs, and venture capitalists. Regarded as the formal gateway between the university and industry, TTOs have been in the spotlight of the stream of researches that views university entrepreneurship as a function of the productivity of their TTOs systems, structure, and personnel's experience (Jones-Evans and Klofsten, 1999; Chapple et al., 2005).

The researches studying the impacts on spinoffs' development find that university support may give a positive signal with regard to the credibility and legitimisation of the spinoff companies (Jain and George, 2007) and endorsement by the university enables the spinoffs to overcome their lack of reputation and raises their chances of survival and growth (Shane and Stuart, 2002).

The strategy, experience and resources of universities and technology transfer offices have an impact on the performance of the spinoff companies.

Indeed, the specific spinoff strategy of individual research organisations has a distinct effect on the strategy and economic profitability of the later companies (Clarysse, Wright, Lockett, Van de Velde, and Vohora 2005). DeGroof and Roberts (2004) suggest that environments

with weak entrepreneurial structure and culture require academic spinoff policies involving high selectivity and high support in order to generate growth-oriented ventures.

In addition, the effective management of university TTOs, a clear university mission in support of technology transfer and the experience of the TTOs' personnel are key factors in enhancing university technology transfer (Siegel et al. 2003; Friedman and Silberman 2003). Lockett and Wright (2005) find that the business development capabilities of TTOs are positively associated with spinoffs formation. Other studies used the resource based view to evidence that the resource stock of universities and the combination of resources are highly important to explain inter-university variations of spinoff activity (O'Shea, Allen, Chevalier, & Roche, 2005; Link & Scott 2005).

Although, the TTOs that choose a high selectively-high support strategy increase their efforts in stimulating disclosures, select the more promising technologies, provide strong intellectual property rights and evaluate the start-up feasibility, but early discovered that funding is the most relevant difficulty in the foundation of a spinoff company (Chiesa and Piccaluga 2000; Moray and Clarysse 2005). Indeed, the level of uncertainty and information asymmetries that obscure evaluations of new ventures is particularly acute in the case of early-stage technology companies because of the difficulty to provide information about a new technological venture to obtain the investors' trust without data relating to previous and consolidated results. The start-ups suffer the inability to self-finance themselves due to the time lag of inflows, occurring only after the market's success, and the lack of collateral to be used for obtaining funds, compared to a prevalence of intangible assets for which it is rather difficult to determine the monetary value.

Another obstacle, generating additional costs for potential investors, is the need for technical and scientific assessments regarding business projects so complex and pioneering that in most cases the investors are unable to grasp fully the real extent of the innovation. Indeed, the best experts on the technologies and products to evaluate are the same promoters of the spinoff searching for finance. The attenuation of the difficulties arising from the lenders' poor ability to evaluate innovative firms encounters a barrier also in the real impossibility to publish all data related to the new projects: there is in fact an inverse relationship between the value of the business idea and the dissemination of information related to it (Bhattacharya and Chiesa, 1995). The result is that new technology-based firms are often financially constrained, with these constraints hindering the firms' growth and even threatening their survival.

The solutions implemented to face the "funding gap" issue has been different: some universities proactively create affiliated public venture funds, dissatisfied with major players

in the process, particularly the pharmaceutical and venture capital communities (Atkinson 1994; Lerner 1999; DeGroof and Roberts 2004). Others have been fortunate to receive assistance through major gifts or local funding and have created innovation centers with grant programs that have demonstrated great leverage and great success.

A third way implemented to address the discrepancy between the demand and supply of seed investments has been through internal gap funding and matching external funding resources focused on the commercialization of inventions. Mustar and Wright (2010) describe the University Challenge Fund in the UK a £50 million seed capital fund established in 1998 by the UK Government to encourage the exploitation of scientific discoveries in universities, to which universities contribute with £20 million. The second round in 2001 led to the establishment of five funds in which 17 institutions are involved.

Harrison (2010) investigates the importance of this public funding: two-thirds of the spinoffs in his sample affirmed that the early-stage seed funding from public sources was important or very important in establishing the business. Lerner (1999) studies the Small Business Innovation Research (SBIR) program, the largest public subsidization of small high-technology firms, and finds that SBIR awardees grow more than the sample of matched firms, especially firms based in US ZIP codes with substantial venture capital activity (California and Massachusetts).

Clarysse, Wright and Van de Velde (2011) with a dataset of corporate and university spinoff find that only in the sample of university spinoffs does start-up capital have a significant influence on growth, and they affirm (p.1432): “It seems that in university spin-offs, a significant amount of start-up capital is needed to realize a specific growth ambition”.

Although it seems to exist a convergence in the literature about the fact that the various public forms of finance boosted the amount of spinoffs created in the mid- and late 1990s (Wright et al., 2006), scholars remain doubtful whether or not these spinoffs will become sustainable companies. Mustar, Wright and Clarysse (2008, p.69) acknowledge that: “Publicly available evaluations of financing schemes are limited and have tended to focus on the number of spinoffs created and funding received rather than their effects (e.g. SQW, 2005)”.

Therefore, the scope to this research is to investigate if the provision of TTO gap funding to spinoff companies at the embryonic phase has an influence in their consequent sales growth and an impact on spinoffs development.

Methodology

The sample, the independent variables and the controls are the same that have been widely described in the previous chapter, so I report only the main information in this chapter.

The data set we analyzed includes the population of 112 spinoff firms founded to exploit inventions assigned to the University of Michigan between 1999 and 2010. The population of spinoff companies was identified from the U-M Tech Transfer's database that collected data about the spinoffs and the gap funds provided to them. Data about the spinoffs' sales and the employees have been retrieved from the Orbis database.

In general, the approach chosen by the U-M Tech Transfer to support spinoffs' activity is the "Comprehensive support and selectivity" academic "spin-off policy" (Degroof & Roberts, 2004).

The variable "TTO gap funds" describes the pool of resources within the university for funding the early commercialization activities of technologies with a strong commercial potential and is measured alternatively by a binary variable coded 1 if the spinoff has received any TTO support and by the hyperbolic sine transformation of the amount of funds obtained by the spinoff firm in Dollars.

$$\text{IHS}(x_i) = \log(x_i + (x_i^2 + 1)^{1/2})$$

Specifically, TTO funds include:

- funds provided by two Michigan inter-universities institutions, MUCI (Michigan Universities Commercialization Initiative) and MIIE (Michigan Initiative for Innovation and Entrepreneurship), and matched by the University of Michigan,
- federal funding resources, SBIR (Small Business Innovation Research) and STTR (Small Business Technology Transfer) grants, for which the TTO provides support in the application procedure.

Spinoffs in the sample received TTO funds from three years before the spinoff's foundation to one year after, with the higher frequency at one year before.

Table 1 defines the study's variables and groups them in the constructs analyzed.

Table 1 - Definition of study variables and descriptive statistics.

Variable	Description	Mean	SD	Min	Max
sales_g	Change in sales (in dollars) between 2007 and 2010	1.39 M	4.26 M	0	20.7 M
sales	Spinoffs' sales in 2010 in Dollars.	2.90 M	11.8 M	0	38 M
emp	Number of employees in 2010.	15.93	39.5	0	285
tto_d	Dummy=1 for spin-off firms that received the technology transfer office funding.	.66	.48	0	1
tto	TTO funds obtained by the spinoff firm in Dollars.	0.76 M	1.14 M	0	4.75 M
vc_d	Dummy=1 for spin-off firms that obtained venture capital.	.46	.50	0	1
vc	Venture capital obtained by the spin-off firm in Dollars.	6.59 M	15.4 M	0	84.0 M
Human capital:					
n_founders	Numbers of founders.	2.34	1.23	1	8
edu	Average number of years of education of founders at university level.	8.92	1.79	4	13
work	Average number of years of work experience of founders before firm's foundations.	17.25	9.01	3	40
Network resources:					
vcexp	Dummy=1 if one of the founders had relations with VC before founding the spin-off	.18	.38	0	1
startupexp	Dummy=1 if one of the founders starts a business before the spin-off	.39	.49	0	1
Age and field controls:					
age	Number of years from spin-off firm's foundation.	5.75	3.36	1	12
Med	Dummy=1 for companies classified in the groups 283 - "Drugs" and 384 - "Surgical, medical, and dental instruments and supplies" with the US SIC Code.	.23	.42	0	1
Software	Dummy=1 for companies classified in the group 737 - "Computer programming, data processing, and other computer related" with the US SIC Code.	.18	.38	0	1
R&D	Dummy=1 for companies classified in the group 873 - "Research, development and testing services" with the US SIC Code.	.35	.48	0	1

Dependent variables

The economic performance of the spinoff companies is measured by inverse hyperbolic sine transformation (IHS) of the sales growth between 2007 and 2010 in dollars.

$$\text{IHS}(y_i) = \log(y_i + (y_i^2 + 1)^{1/2})$$

We compute the IHS transformation because it is an alternative to logarithm transformation when the distribution of the variables is skewed and some of variable take on zero or negative values (Burbridge, Magee, & Robb, 1988). The presence of zero and negative values in the

sales growth distribution suggests that IHS transformation should be preferred to the transformation $\log(y+1)$ to avoid alteration of the regression's beta.

Models

We analyze the distributions of the sales growth between the spinoffs that received and didn't received TTO gap fund and we used the Wilcoxon-Mann-Whitney test, a non-parametric analogue to the independent samples t-test adapt when we do not assume the dependent variable is a normally distributed interval variable, to test their similarity.

Then we examine the change in sales (in dollars) in robust ordinary least squares (OLS) regressions with dependent variable the IHS transformation of sales growth between 2007 and 2010. The variance is not homogeneous along the distribution (heteroskedasticity), so we preferred to calculate the robust standard errors for all the models.

All statistical calculations are performed with the software package Stata/IC 12.

Results and discussion

The average sales of the new ventures are \$ 2.90 million and the average number of employees is 15.93 with a high standard deviation, typical for new venture companies. The average sales growth between 2007 and 2010 is \$ 1.39 million, highly skewed and varying from a loss of \$ -1.73 million to a growth of \$ 20 million.

Correlations between sales growth and venture capital investment are significant (0.23 and 0.27), while the TTO gap funding variables and positive but not significant correlate with sales growth (0.12 and 0.15).

Table 2 - Correlations of study variables

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.vc_d	-												
2.vc_ihs	.96	-											
3.tto_d	.45	.40	-										
4.tto_ihs	.45	.41	.96	-									
5.general	-.04	-.01	.13	.16	-								
6.original	.13	.16	.09	.12	-.02	-							
7.science	.17	.17	.01	.03	-.04	-.06	-						
8.n_found	.17	.17	.13	.14	-.02	.13	-.19	-					
9.edu	-.01	-.02	.22	.23	-.17	-.02	.07	-.06	-				
10.work	-.04	-.01	-.03	-.01	.03	.13	.04	-.22	-.04	-			
11.vcexp	.27	.27	.12	.13	-.13	-.01	.19	.22	-.11	-.02	-		
12.startup	.17	.13	.12	.15	-.13	-.02	.22	.18	-.03	-.11	.32	-	
13.age	.11	.16	.07	.06	.25	-.07	.02	-.12	.04	.30	-.11	-.19	-
14.sales_g	.23	.27	.12	.15	.12	.02	-.04	-.02	.04	.04	.14	-.02	.22

Table 3 - Comparison of spinoffs that received and didn't received TTO gap fund.

	Mean	SD	Min	Max
TTO gap fund = 1				
general	0.33	0.30	0	0.90
original	0.51	0.27	0	1
science	0.52	0.33	0	1
n_found	2.41	1.28	1	8
edu	9.02	1.94	3.67	14
work	17.34	9.35	0	37
vcexp	0.21	0.41	0	1
startup	0.41	0.50	0	1
age	5.99	3.34	1	12
med	0.30	0.46	0	1
software	0.10	0.30	0	1
R&D	0.35	0.48	0	1
TTO gap fund = 0				
general	0.31	0.28	0	0.86
original	0.52	0.26	0	0.91
science	0.51	0.37	0	0.96
n_found	2.15	1.04	1	5
edu	8.28	2.43	3.5	13
work	17.37	8.43	3	35.5
vcexp	0.15	0.31	0	1
startup	0.34	0.46	0	1
age	5.31	3.38	1	12
med	0.10	0.31	0	1
software	0.33	0.48	0	1
R&D	0.34	0.47	0	1

The comparison between the spinoffs that receive or not TTO gap fund (Table 3) evidences that the two groups are similar regarding the patents' characteristics and the education and experience of the founders. The group seems to be different for venture capital and startup experience, but the difference is not significant with the Wilcoxon-Mann-Whitney test (not reported).

It's instead significantly different the industry variation in which the spinoffs operate: the TTO gap fund seems to privilege the spinoffs in medical fields and support less software companies.

We compare the TTO gap funded spinoffs with the spinoffs that didn't received university support. Table 4 shows that the mean sales increase from the end of 2007 to the end of 2010 is greater for the spinoffs that received TTO gap funds (\$ 1.73 million vs. \$ 0.77 million).

Table 4 - Sales growth comparison of the spinoffs that received and didn't received TTO gap fund.

	TTO gap fund = 1	TTO gap fund = 0	<i>p</i> – Value from Comparison
Mean	1.73	0.77	
90th percentile	3.06	1.80	
75th percentile	1.45	0.54	
Median	0.36	0.08	
25th percentile	0.13	0	
10th percentile	0.05	-0.02	
Wilcoxon-Mann-Whitney p-value			0.001
No. of observations	73	39	
Sub-sample of spinoffs that don't receive venture capital financing			
Mean	0.46	0.18	
90th percentile	1.61	0.50	
75th percentile	0.60	0.12	
Median	0.24	0.05	
25th percentile	0.10	0	
10th percentile	-0.02	-0.03	
Wilcoxon-Mann-Whitney p-value			0.001
No. of observations	28	32	

The table summarizes the change in the sales in the 3 years 2007– 2010 of the 112 spinoffs firms. All sales figures are in millions of US dollars.

The distribution is highly skewed: among the spinoffs funded, for instance, only about one-fifth of the observations were above the mean level of sales growth. This skewness finds evidence on the financial and operating performance of other small firms, such as portfolio companies of venture capitalists. At each reported percentile, the change in sales is more positive for the spinoffs funded through the TTO and the differences are consistent along all

the distribution. We test the distributions equivalence and reject the null hypothesis of the equality of the distributions with the Wilcoxon-Mann-Whitney test.

We next examine only the subsample of spinoffs that didn't receive other form of investments, to eliminate the possibility that the results were driven by venture capital investment and not TTO gap fund impact.

Still, at each reported percentile, the change in sales is more positive for the spinoffs funded through the TTO and the differences are consistent along all the distribution. The distributions are significantly different as confirmed by the Wilcoxon-Mann-Whitney test, but now they are less skewed.

In Table 5, we illustrate the results of OLS models estimating the factors that affect the spinoffs' sales growth. The baseline models (models 1 and 2) report an impact of the founders' work experience and the connection with the network of venture capital firms.

The full models (model 4 and 6) have an R^2 of 0.29, the models are statistically different from 0 and the coefficients that are significant are those related to the software (+5.63 $p=0.020$) and research industries (+3.56 $p=0.064$), the founders' work experience (+0.12 $p=0.098$). The experience in dealing with the venture capital industry is not significant only in the full models because of an interaction with venture capital investments' binary variable.

The complete model 4 do not support the hypothesis of a direct influence of TTO gap funds on spinoff's performance, independent from VC financing, while model 6 slightly support the impact of the university technology transfer office on sales growth. In fact, TTO gap funds is significant only when the variables related to the venture capital investments are not entered into the models (models 3 and 5).

Table 5 - The determinants of spin-offs' sales growth.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	OLS	OLS	OLS	OLS	OLS	OLS
VARIABLES	sales_gIHS	sales_gIHS	sales_gIHS	sales_gIHS	sales_gIHS	sales_gIHS
Costant	7.51 (2.09)	4.36 (3.57)	3.87 (4.34)	2.93 (4.34)	4.15 (4.32)	3.26 (4.49)
dum_9901	1.75 (1.60)	1.41 (1.64)	0.40 (1.05)	-0.55 (1.48)	0.27 (1.52)	-0.84 (1.46)
dum_0204	1.05 (1.76)	0.79 (1.78)	-0.11 (1.16)	0.71 (1.56)	-0.16 (1.67)	0.50 (1.57)
dum_0507	-3.85 (2.43)	-4.08 (2.46)	-4.38 [†] (2.40)	-4.03 [†] (2.36)	-4.51 [†] (2.40)	-4.17 [†] (2.37)
med	4.85* (2.37)	4.46 [†] (2.61)	3.40 (2.47)	2.65 (2.24)	3.17 (2.43)	2.44 (2.22)
software	4.58 [†] (2.36)	4.49 [†] (2.27)	5.42* (2.50)	5.63* (2.38)	5.45* (2.46)	5.61* (2.35)
R&D	4.09 [†] (2.22)	3.86 [†] (2.26)	3.88 [†] (2.15)	3.72 [†] (1.98)	3.76 [†] (2.14)	3.56 [†] (1.98)
Human capital: n_founders		0.24 (0.57)	0.11 (0.66)	-0.08 (0.61)	0.07 (0.65)	-0.10 (0.61)
edu		-0.03 (0.28)	-0.10 (0.27)	-0.06 (0.28)	-0.10 (0.30)	-0.06 (0.28)
work		0.13 [†] (0.07)	0.13 [†] (0.07)	0.12 [†] (0.06)	0.12 [†] (0.06)	0.11 [†] (0.06)
Network: vcexp		2.90 [†] (1.69)	2.90 [†] (1.71)	1.36 (1.79)	2.80 [†] (1.68)	1.26 (1.73)
startupexp		-0.18 (1.52)	-0.20 (1.48)	-0.82 (1.44)	-0.30 (1.47)	-0.79 (1.42)
Funding: tto_d			3.87* (1.77)	2.55 (1.70)		
vc_d				4.75** (1.36)		
tto_ihs					0.30* (0.12)	0.20 [†] (0.11)
vc_ihs						0.28** (0.08)
F (12, 99)	1.94	2.00	2.25	2.62	2.34	2.73
R ²	0.13	0.17	0.22	0.29	0.23	0.29
Observations	112	112	112	112	112	112

Note. Robust standard errors are in parenthesis.

[†] p < .10

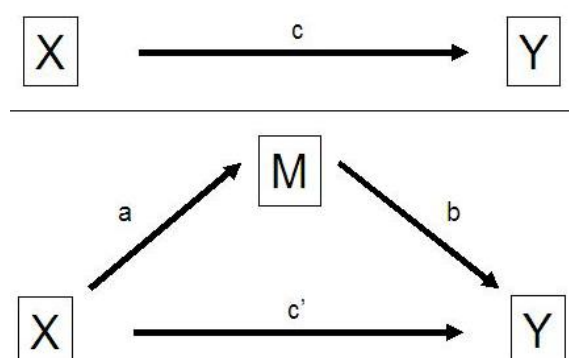
* p < .05

** p < .01

This interaction suggests a possible indirect effect of the TTO gap fund on spinoffs' sales, through the mediation of venture capital follow-on funding.

Baron and Kenny (1986) specify that: "To test mediation, one should estimate the three following regression equations: first, regressing the mediator on the independent variable;

second, regressing the dependent variable on the independent variable; and third, regressing the dependent variable on both the independent variable and on the mediator...To establish mediation, the following conditions must hold: First, the independent variable must affect the mediator in the first equation; second, the independent variable must be shown to affect the dependent variable in the second equation and third, the mediator must affect the dependent variable in the third equation.” (Baron and Kenny 1986, p. 1177). If M completely mediates the X-Y relationship, the effect of X on Y controlling for M should be not significant.



To test the possible mediate effect of TTO gap funding we follow the Baron and Kenney (1986)’s definition of mediation: “A variable functions as a mediator when it meets the following conditions: (a) variations in levels of the independent variable significantly account for variations in the presumed mediator (i.e., Path a), (b) variations in the mediator significantly account for variations in the dependent variable (i.e., Path b), and (c) when Paths a and b are controlled, a previously significant relations between the independent and dependent variables is no longer significant, with the strongest demonstration of mediation occurring when Path c is zero.” (p. 1176).

Paths *a*, *b*, and *c* are tested and estimated by three regressions, Equations 1, 2, and 3 below.

$$M = i_1 + aX + e_1 \quad (\text{Eq. 1})$$

$$Y = i_2 + cX + e_2 \quad (\text{Eq. 2})$$

$$Y = i_3 + c'X + bM + e_3 \quad (\text{Eq. 3})$$

In the causal-step approach, each of the following four steps must be true for mediation to be present:

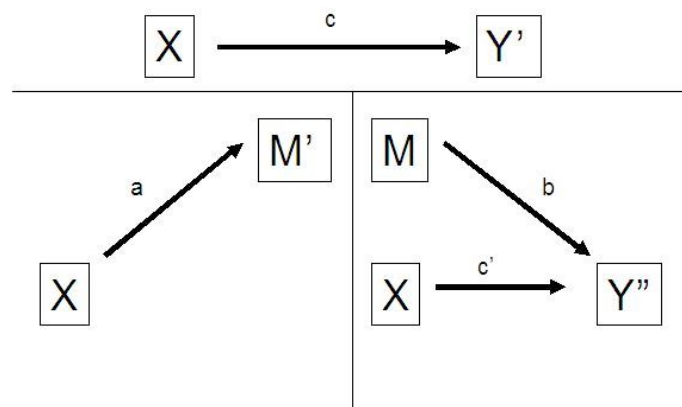
1. the total effect of X on Y (*c*) must be significant;
2. the effect of X on M (*a*) must be significant;
3. the effect of M on Y, controlled for X (*b*) must be significant;

4. the direct effect of X on Y adjusted for M (c') must be non-significant.

Models in which all four steps are satisfied are called fully mediated models (Fritz and MacKinnon 2007).

One way to test the indirect effect is the Sobel test (Sobel 1982): the test is given by dividing ab by the variance $b^2 s_a^2 + a^2 s_b^2$ and treating the ratio as a t test. The variance of the test for binary mediator variable is provided by Kenney's (2008) approach. Another way to test the null hypothesis that $ab = 0$ is to test that both paths a and b are zero. This simple approach appears to work rather well (Fritz and MacKinnon 2007).

In the case the mediator is a dichotomous variable (Preacher and Hayes 2004). The one complication is the computation of indirect effect the degree of mediation because the coefficients need to be transformed.



The four step to verify mediation are tested:

1. Model 3 corresponds to Eq.2: the TTO gap fund variable is significant (+3.87 $p=0.029$) when the VC variable is not present.
2. Eq.1 refers to the second chapter. In fact, we show that the coefficient of TTO gap fund is positive and significant on the likelihood to receive VC financing (model 3 chapter 2: +0.045 $p=0.000$).
3. Model 4 corresponds to Eq.3: in the full model VC financing is the main variable determining the spin-offs' sales growth, in line with many studies demonstrating the important role played by VC financing on the potential growth of the new ventures.
4. TTO gap fund is not significant in model 4 (+2.55 $p=0.135$).

If either the mediator or the outcome is a dichotomy the analysis would likely be conducted using logistic regression when the criterion measure is dichotomous. The amount of mediation is called the indirect effect and with the direct effect, it gives the total effect.

$$\text{total effect} = \text{direct effect} + \text{indirect effect}$$

The effects of the binary mediation using Stata/IC 12 are:

- Total effect = 0.36
- Direct effect = 0.24
- Indirect effect = 0.12.

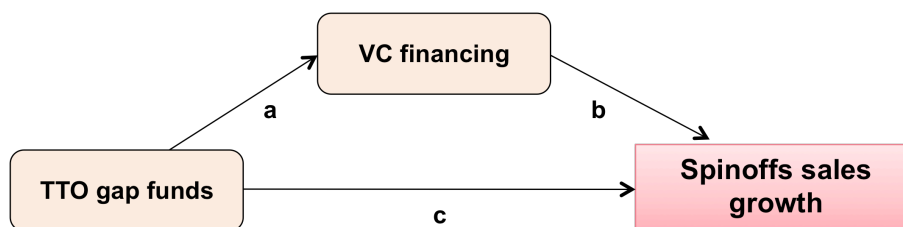


Fig. 1: Model of the relationship between TTO gap funds and spinoff firms performance, measured in terms of sales growth. Path a: the TTO gap funding increases the likelihood of obtaining VC financing. Path a+b: TTO gap funds' *indirect* positive effect on spinoffs' performance, mediated by the impact on VC investments. Path b: TTO gap funds' *direct* positive effect on spinoffs' performance.

The powerful interaction of TTO gap fund and VC investment on spinoffs' sales growth could be appreciate also through Table 6. In Table 6 it emerges quite straightforwardly a clear difference between the three groups of spinoffs, supporting the hypothesis of a moderate impact of TTO gap fund, and a high influence on sales growth of venture capital investments.

Table 6 - Sales growth comparison of the spinoffs that received TTO gap fund and VC investments, only TTO gap fund, any form of funding.

	TTO gap fund = 1 VC = 1	TTO gap fund = 1 VC = 0	TTO gap fund = 0 VC = 0
Mean	3.38	0.46	0.18
90th percentile	6.40	1.61	0.50
75th percentile	2.14	0.60	0.12
Median	0.49	0.24	0.05
25th percentile	0.17	0.10	0
10th percentile	0.10	-0.02	-0.03
No. of observations	42	28	32

Conclusions

The competitiveness of an economic system is strictly related with its capacity to generate innovations, and the ability to transfer them to the industry and society. The shift from systems based on the industrial production to ones more oriented to knowledge and information has increase the interest for the innovation as a fundamental element of the social, industrial and economic development. For this reason, over the past thirty years, there has been a growing interest towards academic entrepreneurship, defined as the direct involvement of academic scientists into the development and commercialization of their research. Universities have gain more autonomy, have matured a new entrepreneurial spirit and have become often sources of spinoff new ventures based upon leading edge research, an increasingly accepted mode of exploiting potentially valuable scientific discoveries.

Universities have established technology transfer offices to act as an intermediary between the university scientists and those who can potentially commercialize the inventions i.e. established firms, entrepreneurs, and venture capitalists. These organizations provide services, critical resources and specific entrepreneurial experience to new science based firms and some of them have also institute “funding gap” programs to compensate for the early stage venture markets’ inefficiencies caused by information asymmetry, cognitive problems and inability to evaluate scientific invention potentialities.

The high public efforts are justified by the belief that spinoffs generate positive externalities: such investments, as R&D expenditures, may have positive spillovers that benefit other firms or society as a whole, but since firms making these investments are unlikely to capture the entire surplus, public support may be an appropriate response. However, the promotion follows an assessment stage where the start-up feasibility is evaluated, considering the industry dynamics, the market trends and the competitive landscape. Indeed, most university researches are not suitable to create a new venture because they tend to be in a development’s very early stage and removed from market concerns.

The University of Michigan’s TTO chose a high selectivity-high support strategy to business formation, sustaining spinoffs with intellectual property rights’ protection services, legal and managerial advice, mentors, connections with venture capitalists and networking events. Furthermore, they provide some spinoffs funding through internal gap funding and assistance in applying to matching fund programs.

The research examines the sales performance of high-technology firms receiving funds through the technology transfer office of the University of Michigan, using the database of all

the spinoff companies created to exploit university-assigned inventions from 1999 to 2010. We compared the growth of spinoffs that received the TTO gap funds with the ones those don't with different descriptive and statistical analysis.

The results show that the sales growth was not uniform, and superior performances couldn't be justified only by the provision of TTO gap funds. We test the indirect influence of TTO gap funding on spinoffs' sales growth, and we find that TTO gap funding has an indirect positive effect, mediated by the VC financing, on the performance of spinoff companies.

Although, TTO gap funds alone seem not sufficient to drive consistent economic performances in the spinoffs, but it substantially improves the spinoffs position the investment markets playing a certification role.

The data on growth are interesting also because they describe a dynamic industrial reality that has been developing and increasing its sales even trough a period of crisis such it has been the 2007-2010 in the United States.

We recognize that this is a preliminary result, with the main limitation regarding the smallness and specificity of our sample; we acknowledge that considering only the spinoffs created by a single university limits the generalizability of the research. Another important limitation is that our analysis has not sought to assess the social benefits of the "gap funding" program. Numerous studies have suggested that, because of knowledge spillovers, social rates of return to R & D are often much higher than the private returns that the firms performing the research enjoy. This analysis has focused exclusively on private returns, as approximately measured through spinoffs' sales growth.

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