

Rizzo, Ugo

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The governance of knowledge in Academic Spin-offs

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The Governance of Knowledge in Academic Spin-Offs

Ugo Rizzo

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Manchester Business School
The University of Manchester
Booth Street West
Manchester M15 6PB

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Author(s) and affiliation

Ugo Rizzo
Facoltà di Economia,
Università di Ferrara
Via Voltapaletto 11
44121 Ferrara
Italy
Email: Ugo.Rizzo@postgrad.mbs.ac.uk

Abstract

The aim of the present work is to study the evolution of organizational knowledge within Academic Spin-off (ASO) firms throughout their life cycle. The exploitation of tacit and indivisible new knowledge developed in the context of academic institutions entails agency problems of different nature; one way to address such challenges is the creation of new business firms by the inventors. At the same time to remain viable and competitive the firm will need to either possess or develop a complex mix of tangible and intangible resources. This work studies the process of firm evolution by looking at the governance mechanisms within and across a Regional sample of ASOs throughout the different stages of their development path. While the scholarly literature indicates implicitly that such a path is unique across all firms, our findings identify a high variety of organizational structures evolution paths undertaken by different firms. On these grounds the study offers some reflections in relation to the theory of the firm.

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1. Introduction

It is widely accepted by both economics and management scholars that innovation is a key vehicle of economic growth and that knowledge and learning are its basic ingredients (see e.g. David and Foray 2002). The positive influence of universities on technological innovation and on knowledge diffusion has been historically documented (Rosenberg and Nelson 1994), and the recent involvement of universities in local development created a strong emphasis on technology transfer activities. Among these activities the creation of Academic Spin-offs (ASOs) has received increasing attention. ASOs are new firms whose business is the translation of knowledge developed within universities into a commercialisable product. At least three reasons underline the strong interest towards supportive policies aimed at enabling those firms around virtually all Western economies: The transfer of new knowledge into the market, the pursuit of revenue for universities, and the positive externalities on the local area (Etzkowitz 2001).

ASOs are first of all new firms, whose initial mission is the exploitation of research results conducted inside the university environment. ASO's role is seen as a bridge between university and industry allowing newly developed tacit knowledge to reach the market as a product (Fontes 2005). Several factors influence the successful completion of this route of development, from policies to physical infrastructure, from researchers' previous industry experience to the scientific productivity of the university, to name but a few.

The existing literature mostly concentrates on two aspects concerning the generation and development of the ASO firm: On one hand the incentive mechanisms that shape the rate of generation or the performance of ASOs; on the other hand the literature focuses on the resource endowment that an ASO firm must own to be successful. Little however is known about the processes of transformation of a business idea into an established firm in the market. While scholars usually emphasise the number or the performance of established firms, few studies so far have attempted to map down and elaborate on the paths an ASO firm undergoes in its development (e.g. Vohora et al. 2004).

The extant literature did not pay much attention to this issue thus implicitly considering the ASO development as a natural path when incentive alignment issues are satisfied on one side and when the resources available to the team, to the university parent organization and to the local context are in place on the other side. This work seeks to fill this gap by qualitatively exploring the evolution of a self-contained population of ASOs. In other words, our key conjecture is that the development paths that unfold before an ASO are multiple. To elaborate this point we will first draw on the ‘theory of the firm’ approaches, as they represent the theoretical background explaining the development and growth of such organizations, and then we will describe the knowledge governance mode taking place within and across the ASO during its phases of development. Considerations about the theories of the firm are brought forward.

2. Theoretical framework

2.1 Theories of the firm

Two main theoretical streams address the issue about the nature and the growth of the firm: transaction costs economics (TCE) and resources based view (RBV). The first approach is based on the transactions unit of analysis and considers the firm as the output of the inefficiency of the market in aligning the incentives of two or more parties (Coase 1937, Williamson 1975, 1985, Langlois and Robertson 1995, Langlois and Foss 1997, Williamson and Winter 1993). On the other side the RBV concentrates on the resources a firm possesses and how they are exploited by the firm (Penrose 1959). The RBV evolves in the so called ‘capability view’ and firms become repositories of knowledge. The cumulability and learning-based characters of knowledge lead to high level of idiosyncrasies in the firm’s growth paths and consequently the theoretical perspective points to a wide heterogeneity of organizational structures (Penrose 1959, Nelson 1991, Nelson and Winter 1982).

Both perspectives appear to develop in a static and incomplete framework. The TCE considers as given ex-ante the production processes and argue that the boundaries of the firm are given only by the trade-off between coordination versus transactions costs. On the other hand RBV

concentrates only on production processes, lacking in the examination of exchange processes across the firm.

A call for a unified approach has been given by Langlois and Foss (1997), whose work points to the need of joining the two perspectives in order to develop a useful theory of the firm. Moreover, although the capability view recognize the importance of the dynamic element, a step further need to be done in order to be able to catch the interdependence of production and exchange processes during time. Grounding on the 'localized technological change' notion (Atkinson and Stiglitz 1969, David 1975, Antonelli 1995, 1999, 2008), Antonelli (2006, 2008) suggests shifting the focus of the analysis from the firm to the governance of knowledge taking place both within and across the firm. The attention shifts from the firm as unit of analysis to a wider class of knowledge governance mechanisms that are involved both within and across the firm: not only external transactions and internal coordination but also a wide set of other interaction mechanisms taking place around the firm need to be considered. The firm is considered now as an organization that produces and uses knowledge and information and that is embedded in a particular environmental context. If we recognise the dynamicity of knowledge as a resource it becomes useful to focus on the governance of knowledge as a variable that change during time. The purpose of the present work is the study of the knowledge organizational modes adopted by the firm in different points in time.

2.2 The ASO firm

2.2.1 Literature review

ASOs are organizations whose main business is the transfer of some research results generated within public research institutions into the market: Differences among typologies of ASOs are not our central interest until some knowledge generated inside public research organizations is exploited via new firm creation. The aim of the present section is gathering economic and management literature findings about the organization of the production and exchange processes and their interdependences, that is the governance of knowledge, about the ASO firm.

The phenomenon of ASOs has been significantly explored over the last two decades, both

quantitatively and qualitatively (Rothaermel et al. 2007). The literature mainly concentrates on the determinants of ASOs, but few studies, more recently, addressed the development of ASO firms (Mustar et al 2006). The determinants mainly relate to the number of firm created or to their performance. In both cases the analysis relate ex ante available and known factors – the so called determinants – to the situation at a fixed point in time in the life cycle of the spin-off firm, that can be referred to the number of activated ASO (see e.g. Di Gregorio and Shane 2003, Shane 2001, Lockett and Wright 2005, Powers and McDougall 2005) or to the performance in terms of success (see e.g. Shane and Stuart 2002, Audretsch and Lehmann 2005).

University research results are highly tacit in nature because the understanding is restricted to a narrow number of experts (Antonelli 2005): The relevance of the determinants in fostering the generation and development of ASO firms is therefore mainly due to the lowering transaction, interaction and coordination costs needed to exploit such tacit research results. The determinants are important in our perspective because they highlight the ideal environment and firms' characteristics that increase the likelihood of ASOs to be generated and/or to succeed. The scrutiny of the determinants has been conducted from different perspectives: Focus is on the university and Technology Transfer Office (TTO), on the individual, team or on a geographical area.

Amongst these stimulating factors it is worth highlighting the presence of patents (Colyvas et al. 2002, Shane 2002, 2004), their scope (Shane 2001) and effectiveness (Shane 2002); the entrepreneurial capabilities of the CEO¹ and of the spin-off team (Chiesa and Piccaluga 2000, Clarysse and Moray 2004); the previous experience, either of the university or TTO in dealing with technology transfer activities (Friedman and Sielberman 2003) and in ASOs generation and development practices (Lockett and Wright 2005, Powers and McDougall 2005), or in having undertaken activities with the industrial world, both at the institutional level of university and TTO (Lockett and Wright 2005, Powers and McDougall 2005) and at the individual level of the researcher or team of the new venture (Landry et al. 2006, Krabel and Mueller 2009); the presence of supporting policies both at the national or regional level (Baldini et al. 2006) and at the institutional level of university (Friedman and Sielberman 2003, Chang et al. 2009); and finally the venture capital (VC) availability (Chiesa and

¹ Several works investigated the trade-off between training the scientist with managerial capabilities or involving a surrogate entrepreneur (e.g. Franklin et al. 2001, Clarysse and Moray 2004). Clarysse and Moray (2004) find that forming the academic to be a CEO is probably the best choice because of recognition from the team and technical reasons.

Piccaluga 2000, Powers and McDougall 2005, Henrekson and Rosenberg 2001). The VC availability is positively related to the generation of ASOs also because it provides network assets to the ASO firm: higher the ex-ante networking assets of the founders, of the university and of the TTO, higher is the incentive to the formation and success of ASOs (Colyvas et al 2002, Friedman and Silberman 2003, Grandi and Grimaldi 2003, Zucker et al 1998, 2002, Krabel and Mueller 2009, Jain et al 2009).

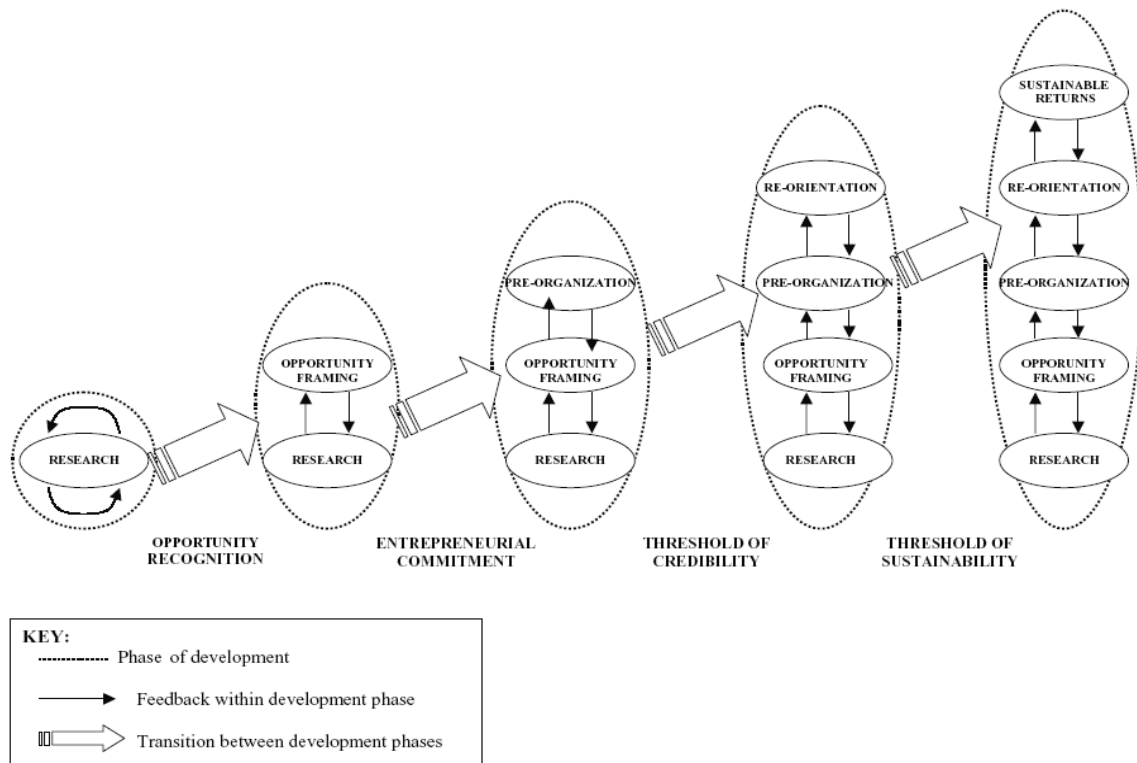
With regard to the development of ASOs, literature has addressed mainly two stages of the process: The creation and the development process. With regards to the creation stage, works have been widely concerned with the determinants of the ASO creation, and few studies address a different question about the creation of an ASO; that is why the academic spin-off firm has been chosen as a means of exploitation instead of going to the market via other commercial route. To this end Shane (2002) and Fontes (2005) point to the agency issue reduction function of the entrepreneur needed to exploit the tacit knowledge characterizing the research results, while the Lambert Review (2003) and Minshall and Wiscksteed (2005) find some intrinsic characteristics of the invention leading to such a way of exploitation: when the invention is a platform technology, when it needs further development, both in terms of technology and in terms of IP rights, and when the technology reveal high level of fungeability, that is when a technology has many different applications.

With regards to the development process studies are, again, mostly related to the identification of the determinants that lead to successful ASOs in terms of performance in static comparative analysis (see e.g. Shane and Stuart 2002, Audretsch and Lehmann 2005). The development of ASOs in a dynamic framework seems to be less explored. In this regard the seminal work by Roberts (1991) identifies three main stages of development for a general new-technology-based firm, mainly related to the capacity of getting financial investment funds: Start-up, initial growth and sustained growth. Some works recently investigated the issue at the ASO level (see e.g. Vohora et al. 2004, Clarysse and Moray 2004 and Shane 2004). Clarysse and Moray (2004) undertook an analysis of the general new venture start-up phase which an ASO follows, by deeply examining a single case study. The authors indentified four phases a team needs to encompass in order to be able to carry a market efficient productive activity: Idea, pre start-up, start-up and post start-up. The authors explore the evolution in the decision making process and in the human resources organization of the firm: The findings reveal that hierarchies are very flat until the third phase and a slow learning process that leads to the institutionalization of the organizational structure of the firm which is required to get to

the fourth phase. Moreover they also investigate the reasons to this adaptation route: Market preferences and external shocks appear to play a main role in shaping the decision making process and its organization.

In a different approach Vohora et al. (2004) propose a dynamic perspective on the acquisition and building of capabilities processes during the ASO creation and development route. By pointing to the importance of different sets of knowledge at different points in time during the ASO life they identify five phases and four critical objectives to be reached in order to be able for the firm to move to the next phase of development. The ASOs life cycle starts in the academic research context, where the recognition of a business opportunity is the critical step to pass in order to get to the next phase, that is the so called opportunity framing. The first critical juncture is given by the acquisition or availability of some knowledge about the market characteristics in order to be able to recognize an opportunity of business. The second phase, the opportunity framing stage, consists of shaping the business idea into a firm perspective; and, in order to get to the next phase, the ASO team needs to get an entrepreneurial commitment. There are two main routes to accomplish this task: Hiring a surrogate entrepreneur or train the scientist with entrepreneurial competences. The third phase is called pre-organization and consists of the development of targeted strategies and their implementation. This entails how best to structure the firm to develop the required capabilities that are necessary to accomplish its strategic goals. This means making choices about which capabilities to develop, which should be built internally and which should be acquired externally. This represents probably the fundamental phase of the ASO life cycle. It is the stage in which a core product is established as the main activity of the firm and where complementary assets and their coordination become crucial. Networking activities are therefore fundamental in this phase. Once the main strategies are settled the firm needs to be able to secure financial investment in order to further develop the technology. This critical step is called credibility and once it is obtained, the ASO reaches the fourth phase, the so called re-orientation that comprises the ability of continuously managing the identification, acquisition and adaptation of useful resources. When the ASO reaches a sustainable rate of growth, the last critical juncture is overcome and the ASO gets to the last phase of development, the so called 'sustainable return phase', where the firm is able to dynamically respond to market needs and changes in a Teece et al's (1997) dynamic capability perspective.

Figure 1: ASO firms' life cycle



Source: Vohora et al. (2004, p. 152)

This Vohora et al (2004) study contributes to the understanding of the evolution of an ASO firm. The authors have highlighted in great detail the challenges an ASO has to face in its life, resulting in the formation of an ASO life cycle. They argue that the stages identified characterize all the ASO life cycles: it seems the path of ASO evolution to be unique; they do not explore the heterogeneity of routes ASOs undertake in order to get from an idea of business to a market set company. In the present study we will adopt this life cycle framework to investigate the evolution of our population of ASOs, adding a caveat: The life cycle adopted here is not related to some technological evolution as the traditional contextualization of life cycle (see e.g. Utterback and Abernathy 1975). The purpose is not of identifying a dominant design or standard, but the attention is posed on the firm' evolution in terms of the capabilities it needs to build or acquire in order to proceed in the growing stages.

2.2.2 The ASO firm profile

One of the conjectures of this work is that a theory of the ASO firm does not exist per se. Nevertheless from the literature it is possible to derive some insights about best practice of ASO firm. In this section our purpose is to match the characteristics of the ASO firm as they emerge from the literature with the characteristics of the innovative firms acknowledged by the economic and management literature. In order to do so we will match the elements highlighted above so far, with the main type of characteristics of the innovative firm identified by Teece (1996). The author first identifies some organizational factors, which are hierarchies, integration, scope, changing culture and external linkages; then he distinguishes five typologies of archetypes of an innovative firm, according to different combination of degrees of organizational factors. The archetypes range from the Multiproduct firm highly vertical, highly integrated, with a wide scope, low changing culture and low external linkages, to the stand-alone laboratory that is not integrated and not hierarchical, but with strong external linkages, narrow scope and high changing culture. Moreover the paper highlights how a stand-alone laboratory needs to exploit patented invention in order to succeed. When we compare ASO firm characteristics with the types of innovative firms identified by Teece (1996), it appears that the literature refers to ASO as a middle ground-type of firm in between the stand-alone laboratory and Silicon Valley-type of firm. A Silicon Valley-type of firm has the same scope, changing culture and external linkages of the stand-alone laboratory, but show some level of hierarchies and of vertical integration, not as deep as the Multiproduct firm, but more than the stand-alone laboratory. Let us now consider each of the organizational determinants in the ASO firm.

In terms of culture, ASO firms can be considered either as stand-alone laboratories or Silicon Valley-type of firms, because of their innovative nature and their intrinsic high level of adaptability: ASOs are new firms that have to find a way into the market and the ability to be able to adapt to this new scenario is vital. Relative to the hierarchy the ASO firm appears to behave like a stand-alone laboratory: A spin-off firm at an initial stage of development will have a mainly flat hierarchy that will probably develop with the growth of the firm (see e.g. the case-study explored in Clarysse and Moray 2004). In terms of vertical integration it is natural to assume that a new innovative firm will be quite specialized and not integrated: The newly created firm will base its production process on a main product, that is to say the scope is highly limited and specialized.

One of the main organizational factors impacting the ASO creation and development are external linkages. The highly technological and innovative character of most new products

requires the development of horizontal as well as upstream and downstream linkages. The literature just analysed shows how relationships with industry are fundamental in order to develop an ASO idea. Working with industry means knowing the industrial requirements in terms of product development, but it also means that knowledge about the availability of different capabilities in the environment, or for the demand of complementary assets is gained. Complementary assets can be general when easily available in the market or specialized and co-specialized when the interaction between the buyer and the seller is significant in order to positively conclude the transaction (Teece 1986, 1988). The industrial world provides mainly the downstream and horizontal set of linkages. These represent on one hand the channel to eventual complementary assets and on the other hand the sources of market knowledge necessary to get a product to the market. Upstream linkages with the university also appear to be important for three main reasons: First an ASO can derive benefit from access to university facilities from the beginning of its life; second, the university or TTO can provide networking assets to the ASO firm; and finally universities represent a source of scientific capabilities in the development path of a spin-off, both in terms of research results and human capital.

Another relevant element influencing the networking assets of an ASO is the external environment: Two main factors are indicators of the environmental strength: supporting policies and high tech firm concentration. Supporting policies appear to play a fundamental role in improving the rate of commercialization activity of universities and individuals. The environment is then enhanced by the presence of high tech firms or at least firms that transact and interact with ASOs. The main reason is again the dense networking activity of the locality: Placing the ASO in an area with high tech firms should significantly reduce the networking costs and the connected coordination and transaction costs on the one hand, and provide a wide availability of capabilities in the context of the ASO on the other (Friedman and Silberman 2003).

The ASO firm profile emerging from the ASO determinants literature is similar to the Silicon Valley-type of firm with some characteristics of the stand-alone laboratory. In particular the organizational factors of hierarchy, changing culture, scope and external linkages appear to be very similar between the Silicon Valley-type and the ASO firm structures, while the low level of vertical integration of the ASO firm appears to be closer to the stand-alone laboratory profile. Another factor leading to similarities with the stand-alone laboratory is the emphasis put on protecting the invention with a patent because of the difficulties in exploiting a highly

tacit knowledge. Finally, the environment where ASOs are usually studied, appear to be similar to those of Silicon Valley-type firms, because of the high concentration of high tech firms necessary in order to get high networking activities.

Summing up, economic and management works are based on an ASO firm profile that tends to the Silicon Valley-type of firm. In order to move from an idea of business to this type of firm configuration scholars highlighted some obliged step and some critical junctures to be overcome by the firm. Our research question therefore point to the investigation of the mechanisms that lead an idea of business to become a literature-style ASO, that resembles the Silicon Valley-type of firm. Is it a unique or dominant path as it is assumed by the literature, or not? In order to answer our research question it will be used the integrated approach proposed by Antonelli (2008) that ground on the notion of localized technological change and that puts the focus of the analysis on the knowledge governance mechanisms. We will therefore investigate the evolution of knowledge flows taking place within and across the firm during three main phases of development of the ASO firm. To do so the following empirical analysis seeks to describe the evolution of the ASO firm in terms of combination of external versus internal knowledge adopted by the firm in order to carry out some selected business activities.

3. Empirical analysis

3.1 ASO in Emilia Romagna

In this chapter we shall analyse the creation and development of ASOs in the Emilia Romagna region, located in the north of Italy. Emilia Romagna represents one of the richest regions in Europe in terms of GDP per inhabitants (Eurostat 2007). In the Italian panorama Emilia Romagna represents one of the most innovative regions: The intra-muros expenditure in R&D and the average number of researchers per inhabitants are among the highest in Italy (Istat 2005). The concentration of high tech firms in Emilia Romagna is the 3rd highest in the national context, although the only available data refers to 2001, where the region accounted for 9% of Italian high tech firms, just below the Lombardia and Piemonte regions (Istat 2001).

The Emilia Romagna region is shaped and characterized by certain factors meaning that the region can be considered as a self-contained economic system. The limited geographical area in which a high number of SMEs are involved in robust networking relationships, and the consequent high level of labour division inside the region and the elevated level of institutional activities, have resulted in the acknowledgment by scholars of the presence of internal patterns of idiosyncratic evolution (Brusco 1982, Leonardi and Nanetti 1990). Institutions played and continue to play a central role in the evolution and behaviour of the regional economic system: The Emilia Romagna region is shaped by a significant amount of intermediary institutions that enhance information transfer in the environment, by the important presence and influence of government institutions that learn and evolve inside the system and by self-monitoring and evaluating tools that produce idiosyncrasies in the local institutions and practices (Bianchi and Giordani 1993).

In recent years the region developed an institutional framework with the aim of governing and coordinating the networking activities among universities and public research centres; a unique regional innovation policy in the national context (Poma and Ramaciotti 2008) has been put in place in order to promote innovation and knowledge networking activities inside the region. Within this framework, in the sphere of the POR (Regional Operative Programme) under the third objective of the ESF (European Social Fund), the ‘Consortium Spinner’, activated in 2000 aimed at the promotion of employment in research and technological innovation positions. The Consortium represents the five universities and the three public research institutions of the region. The objective of Spinner is the realization of projects aimed at the valorisation of human capital, promotion of research, technology transfer and innovation activities, also and above all by the creation of new ventures. The first Spinner Program took place between 2000-2006, whilst the second started in 2007 and will last until 2013.

The aim of this section is to present the results of our investigation: The comparison amongst the different routes undertaken by the different ASOs, investigated by means of the evolution of the ratio between internal and external knowledge relative to the different business activities. We will therefore describe the different organizational configurations developed by the combination of internal versus external knowledge in conducting the business functions (R&D, production processes, commercial function, training of employees, IP management and, as a result of the previous factors, the governance that is the ratio between transaction and coordination). The research is based on ten face-to-face interviews with ten academic

spin-offs from the Emilia Romagna region: At least two firms per university were contacted and directly interviewed using a semi-structured questionnaire². The methodology adopted in this work allowed us to compare different case studies in order to produce independent analyses to be compared amongst themselves (Yin 1994). The research was aimed to explore the evolution in the governance of knowledge by ASO firms: Three different stages of ASOs life have been identified: Time T_0 represents the constitution of the ASO firm, that is the reaching of the entrepreneurial commitment in ASO life cycle (Vohora et al 2004); time T_1 is reached by the ASOs after the pre-organizational phase, where credibility has to be obtained to pass to the next phase; time T_2 represents the means of access to the sustainability growth phase.

3.2 Governance of knowledge in ASO firms

3.2.1 Phase 1: Research and opportunity framing

According to Vohora et al. (2004), the starting point in the ASO firm's life cycle is given by the identification of a business and the choice to exploit that idea via new venture creation. Bringing the idea to the market consists of the development of an opportunity frame and of an entrepreneurial commitment by the team of inventors. This phase always takes place inside the university but different reasons motivate different teams to decide such a path of exploitation. The general firm's generation process supposes the existence of profit potentialities, and we assume that business revenues are expected by all the inventors moving toward a spin-off activity: This reason is a sufficient determinant to generate a firm per se, but clear ideas of business are not present in all cases at an early stage as in the phase we are exploring. Our population identified three additional non-exclusive motivations moving the inventor team to undertake the ASO practice:

- (a) University push on a department or research group of excellence of the university
- (b) Research funding of a big corporation to a university department or research group
- (c) Precarious (short-term) researchers desire to get a job

² One university has not been taken into consideration because it generated only one ASO so far

The three reasons are in some cases overlapping: For example one interviewee based the choice of exploitation mechanism of ASO because of a conjunction of points (b) and (c), and because of a particular approach to scientific and academic research of the research group where the business idea has been generated:

“In 2004 a large corporation contacted the research group of our professor in order to finance the study of 20-60 molecules: An important volume of work. The professor has a precise idea of academic research: It has to be half pure and half applied. This fund would have shifted the research group’s attention to the applied research (more or less 80% applied versus 20% pure) going against the philosophy of the professor who was head of the research group. This opportunity, together with the difficulties in getting a permanent position within university, make two students (one Ph.D. and one just graduated), supported by the professor, start a new venture firm in order to work on this privately funded research project.”

Once the idea of a business has led the inventor or the team to decide for an ASO way of exploitation, an opportunity of business has to be transferred in the market by the development of an entrepreneurial commitment (Vohora et al. 2004). In situation (b) the neo-ASO firm gained more easily an entrepreneurial commitment than in the other cases, because the private funding to some specific activities was already conferred to those activities with a marketability character on one side and knowledge market feedback on the other side. For example, in order to highlight the importance of the first private fund that gave birth to the firm, one ASO said:

“We are a spin-off of the University of Modena and Reggio Emilia, but also of C.³”

In the other two situations, (a) and (c), the business opportunity and an entrepreneurial commitment have to be shaped inside the parent research laboratory or department, by identifying some new products with a potential value for the market place. In order to develop a sufficient entrepreneurial commitment, some tools have been recognized as leading factors:

- (d) Previous industry experience
- (e) Spinner Consortium support
- (f) Market feedback

³ Abbreviation of the large corporation giving the first fund to the firm

One of these tools, point (e), has been present from 2000 and eight out of ten of the population of firms benefited from this tool, including the two privately funded firms. The two Spinner-not-benefiting firms were born before the supporting tool was put in place. One of them (with $t_{0,4}$ configuration) born out of the university push and on the long-term forecasts of the head of the research group from which the firm took place, professor X:

“In the beginning there was an idea based on *let's try*. [...] The potential market was there since the beginning in the mind of the professor. At an engineering level the attention to industrial application is always high, and an expert professor like X knows the potentialities of the innovation.”

In these Spinner-not-benefiting cases, the new product market feedbacks generated the entrepreneurial commitment, while in the other Spinner-not-benefiting case the ASO was mainly born as a solution to the precarious position of the team members inside the university and the entrepreneurial commitment has been put in place mostly by the previous industrial experience of the founders.

All the other firms, generated more recently, benefited by Spinner supporting tools. These firms have been able to build an entrepreneurial commitment mainly because of the set of activities set by the policy. Spinner grants gave the researchers/entrepreneurs one or two years wage in order to test the feasibility of the opportunity. The grants gave the teams the time to further develop the technical idea on one hand and on the other hand the possibility of being taught about complementary activities, such as IP consultancy, managerial and administrative competences, marketing activities, VC findings and writing a business plan. Almost always the grants have been won by more than one funder associate and therefore gave different team members the opportunity to specialize in different competences:

“The idea of business born before Spinner. Spinner taught us not only from a technical perspective, but also from a managerial and administrative viewpoint. The grants were all the same, but you could choose different subjects, so the three of us took different specialization courses: one based on management and administration, one on the marketing and commercial function, and one on the technical part.”

In some occasions the grants led to the building of some network relationships to get the first jobs even before the ASO took place: In this case Spinner and the consequent market feedback given by the first jobs, provided a reasonably strong entrepreneurial commitment.

Once this *critical juncture* was reached, the firm takes its place and enters the market at time T_0 , reflecting a particular organizational structure.

We can recognise four different organizational structures at time T_0 , dispersed in the population of ten newly founded firms. At this stage, the firms show the highest level of deverticalisation, where the majority of the functions are carried out by turning to the external environment. That is to say the external linkages play a fundamental role in allowing the interactions and transactions with the environment, and therefore allowing the acquisition of external capabilities on one side and permitting the generation of knowledge that lead to other capabilities development on the other side, in an evolutionary process (Metcalf and Ramlogan 2005).

It is possible to note that the R&D function at T_0 is always mainly developed in the parent organization. Several firms of our sample started the entire business activities when still in the laboratories of the parent university, while all of them are born on some R&D conducted in the parent organization and in the beginning are highly dependent on the parent organization's knowledge. Also in the case where the product object of the ASO business activity is a service in the form of pure consultancy, the competences and capabilities to be exploited rely on the parent university, in order to be adapted and developed for the market. The production function is in half of the cases mainly made from firm internal competences, while in the other cases is more dependent on external resources. In some situations the physical production is done inside university laboratories, also for what concerns the pure manufacturing phases. It derives atypical organizational structures for firms within the university, as one of our interviewees explained:

“Initially university buildings were used: A firm with the head office within a university laboratory is something anomalous. Any organizational structure was lacking. The manufacturing processes were hand-crafted and conducted in the university laboratory.”

Similarly to the productive function, the commercial function shows significant differences amongst firms: Four firms entrusted a person to this role with the aim of building a link within the market place, while six did not and based the function only on the previous network assets, which is an internal resource already available in the firm. The other functions appear to be based on external knowledge in all cases: The employees, which just in a few cases are not only the associates of the ASO, derive their training from the parent institution and the IP issues are always done, when present, with the advice of an IP consultant, often

derived from the Spinner network assets. The consequent functioning of the firm is based more on external than internal knowledge in all the ten interviewed firms.

The table shows the five different compositions at time T_0 . It highlights the level of internal versus external knowledge on which each firm managed some identified functions:

- R&D: Research and Development
- Prod: Productive processes
- Comm: Commercial function
- Training: Training of employees
- IP: Intellectual Property issues
- Gover: Overall knowledge governance of the firm
- Firm no.: Number of firms in the configuration

Then the ratio between internal and external knowledge used to accomplish the identified functions is categorized in:

- H: High dependence of the function on internal knowledge
- L: Low utilization of internal knowledge, that means high dependence on external knowledge

For what concerns the commercial function a third level of detail in the governance of knowledge was needed in order to classify different approaches of firms to the function and the label “I” for intermediate governance of knowledge has been put forward. Furthermore, a function not accomplished by the firm has been labeled as “x”.

Table 1: Governance of knowledge in the different functions at Time T_0

	$t_{0,1}$	$t_{0,2}$	$t_{0,3}$	$t_{0,4}$
R&D	L	L	L	L
Prod.	H	L	H	L
Comm.	H	H	I	I
Training	L	L	L	L
IP	L	L	L	L
Gover.	L	L	L	L
Firms no.	2	3	3	2

It seems clear that the organizational structure of the ASOs at this point in time in their life cycle is very basic; it is similar to the stand-alone laboratory type of organization (Teece 1996), that is characterized with low levels of vertical integration, almost no hierarchies, possibly some horizontal integration given by the different competences assembled together (especially the firms exploiting consultancy services), quite a specialized scope and above all highly dependent on the external environment. In this semi-organized structure all the firms get to an entrepreneurial commitment, and they enter the pre-organizational phase, where, as seen in the previous chapter, the main decision about how to organize the development and acquisition of resources are taken.

3.2.2 Phase 2: Pre-organization

This phase represents the critical step in the development of the ASO firm. It is in this phase that the firm needs to develop a first organizational structure in order to face the market: That means “taking decisions over what existing resources and capabilities to develop, what resources and knowledge to acquire now and in the future, as well as when and where to access these resources” (Vohora et al. 2004, p. 156), and it could be added that also means developing processes (routines and capabilities) of implementation of these decisions. In this phase, the firms have to get *credibility* in order to pass to the next phase: According to Vohora et al. (2004) credibility is given mainly by the capacity of getting funding from investors in order to acquire the needed resources. In our analysis we broaden the concept to the capacity of putting a product into the market that generates revenues and incentives to go further into the growth and expansion of the firm, with connected organizational changes and adaptations.

The decision processes and the consequent changes in the firm’s organizational structure taking place in this phase is reflected, in our analysis, by the differences between the T_0 and T_1 inter-firm configurations. The four configurations acknowledged at the point T_0 has evolved in eight different configurations. One firm did not make any organizational change and the functions remain dependent to the external or internal capabilities exactly in the same way as at the T_0 point. This firm, represented by configuration $t_{1,1}$ born with the aim of positioning as an outsourcing research facility of big chemical and pharmaceutical corporations that at the time were generally experiencing increasing rates of R&D outsourcing. The spin-off born on some university patented technologies sold back to the inventor in exchange of equity share in the ASO capital: The ASO had therefore an agency

issues reduction function and the development of the technology to a more advanced state-of-the-art (Shane 2002, Fontes 2005). The ASO mission was therefore to invest in the development of the patents in order to make them attractive in the market (Minshall and Wicksteed 2005). The original idea as initially conceptualized has not been practicable for long time because the development of the patented technologies was still far to a development point suitable for the client firms:

“The initial activity was based on the generation of synthetic molecules/reagents: For two years we sought the idea of selling in the market patents related to the aforementioned synthetic procedures. When we understood that in order to get these molecules into the market a further development for 500.000 euro was needed, we sought to sell the embryonic invention to a firm willing to develop it. But market firms wanted more proof, more information and more investments: The stage of development of our products were too initial. Those patents remained therefore in house and have not been exploited, nor extended outside Italy.”

The core activity therefore changed quite soon, because the initial idea was not giving back the expected profits and feedbacks. The financial availability has always been limited, because the R&D was fed by the reinvestment of the profit, and no VC or Business Angels invested in the firm, because, in the former CEO's words, “they are looking for the discovery of the century”. The change in product development did not produce any organizational change in terms of knowledge governance of the firm: This can be also noticed in the cultural and routine maintenance after the change:

“Because of the difficulties in getting to the market caused by this gap of investment nobody wants to finance, the business changes: We started to focus on something needing less development, something that when proposed should not scare firms. We started working *on the natural* where nowadays we possess a set of interesting patents. Also in this filed [...] our products always lack of a complementary market analysis and proof of future revenues. We produce new ideas, this is our job. We are a good supplier (and our ideas get into the market) when working with strong and established partners, which the link is often an old one, dated back before the generation of the spin-off.”

In the other seven new organizational configurations observed in time T_1 a common tendency towards an internalization process is noticeable, but the different strategies show a high level of variety produced by different structuring paths. The R&D function has been internalized in four firms and just one remained linked to the parent organization; in the other four firms it is no longer carried out: This is the case of pure consultancy services spin-offs. Two of these

ASOs have been generated on an idea of business based on both a physical product and a set of correlated services. Between the opportunity framing phase and the pre-organization phase the unfeasibility of the physical product business emerged, and the activity of the firm flowed only in the services business, so slashing the R&D function:

“The initial idea of the business was about the production of scientific documentation linked to naturalistic topics, to be diffused via multimedia channels. In 2003 IT were experiencing high level of interest and growth; UMTS technology had just appeared and the idea of business was generating a firm which was able to create specific media files applicable to a wide variety of information technologies such as the mobile phone. Our firm would have produced the service and the final product should have been produced in conjunction with the technical support of a private firm. The main targeted consumers of the new product were public institutions such as natural parks, schools, etc, and the squeeze in public expenditures obliged us to change strategy”

The four only-service-based firms (all firms in configurations $t_{1,5}$, $t_{1,6}$ and $t_{1,7}$) showed some similar changes in terms of overall governance of knowledge, moving toward an internal organization.

The productive function has been internalized by seven firms; the other three remain linked to the external knowledge in order to develop the productive process because of the physical complementary assets, at this stage in all cases of generalized nature, easily procured in the market place:

“The idea has always been a product: The business born on a set of new ideas condensed in the product, where the product value added was given by the good ideas, not by the hardware per se. [...] The business starts on a product simply based on the union and assembly of already existing hardware pieces (an idea relatively new as all the modules were already available in the market) with a newly written ad-hoc software.”

In some ASOs the degrees of influence of external versus internal knowledge changed just in few functions, while in other ASOs the new configuration represents a big step in the organizational evolution taking place in the pre-organizational phase of development of the firm. It can be argued that four firms moved from a high decentralized configuration to a highly internalized configuration (one firm moving from $t_{0,1}$ to $t_{1,5}$, two firms in $t_{0,2}$ moving one to $t_{1,6}$ and one to $t_{1,9}$ and a firm in $t_{0,3}$ moving as well to $t_{1,9}$) showing few functions based mainly on external knowledge at time T_1 .

The comparison between T_0 and T_1 also highlights the common tendency to shift from external toward internal knowledge in the governance of the R&D and training of employees functions. The inverse route took place concerning the commercial function: Usually based just on previous network at T_0 , the function get more connected to the external environment usually by a specific human resource, although the previous network continues to play an important part of the function.

The commercial function evolution of one ASO is explicative about the acquisition and development of market knowledge. They have been generated on a private fund, that is on the previous network assets of the parent organization, that allow the team to finance the first year of activity of the firm, especially in the physical investment assets which are very important for this chemical company. In order to develop new clients they almost immediately started organizing a conference activity at the national level in order to make the pharmaceutical companies potential clients *in primis* aware of the development of the research about the field of study of the firm and of the parent group of research:

“Every year we associated a workshop activity to the research and production activities, in order to both disseminate our competences and make the Italian companies (now also international companies) aware of the scientific society’s progress in the field of solid state drugs. [...] This activity acted as showcase for us: After the first workshop we activated two more pharmaceutical clients, who committed parts of research they were conducting to us.”

With regards to the IP issues and training of employees, at time T_0 both based on external knowledge for all the firms of the sample, we noticed different behaviours: the IP management, apart from two pure services firms that do not carry this function, remains in all cases linked to external consultancy. Conversely, the training of employees were in half of the cases internalized within the firm boundaries. The reasons for this internalization of knowledge governance is mainly due to the fact that new employees in this stage are mainly assumed to carry out R&D and designing functions, in some cases starting to be related mainly to the market feedbacks rather than on the upstream source of knowledge.

Table 2: Governance of knowledge in the different functions at Time T₁

	t _{1,1}	t _{1,5}	t _{1,6}	t _{1,7}	t _{1,8}	t _{1,9}	t _{1,10}	t _{1,11}
R&D	L	x	x	x	H	H	L	H
Prod.	H	H	H	H	L	H	L	L
Comm.	H	I	I	L	I	I	I	L
Training	L	L	L	H	H	H	H	L
IP	L	L	x	L	L	L	L	L
Gover.	L	H	H	H	H	H	L	L
Firms no.	1	2	1	1	1	2	1	1

To sum up, the four initial configurations which were mostly decentralized and dependent on external bits of knowledge, moved into a higher variety of configurations. The movement is mainly centered on the paths of internalized sources of knowledge, that is to say, at time T₁ the firms appear to be more dependent and to base their business activity mostly on internally developed knowledge. The eight configurations at time T₁ show the prevalence of importance of internal knowledge, but few examples of decentralized configuration are still in place. The stress is on the high variety of structural configurations obtained at the end of the pre-organizational phase, covering a range of different possible configurations going from a strong internal knowledge governance (configuration t_{1,9}) to one almost completely based on external knowledge (configuration t_{1,11} and t_{1,10}) structure.

What emerged from the analysis undertaken was that moving from T₀ to T₁ produces changes in a more or less common path toward less dependency on the parent organization's source of knowledge, and toward a higher dependency on the external environment regarding the commercial function. This highlights the need of developing a sort of market knowledge that can be gained only by connecting the firms within the downstream context. The several combinations of internal and external governance of knowledge possibilities produce a high level of different paths undertaken by the different ASOs in order to get past the credibility threshold. In the next section, we will discuss the evolution of the firms which reached this point of credibility and therefore moved towards the re-orientation phase in order to get to a sustainability threshold, as outlined by Vohora et al. (2004).

3.2.3 Phase 3: Re-orientation

In this phase, “the entrepreneurial team faced the challenges of continuously identifying, acquiring and integrating resources and then subsequently re-configuring them” (Vohora et al. 2004, p. 157), until they get to a sustainable rate of growth which represents the next and last phase of the ASO’s life cycle. In this phase, the organizational structure of the firm should evolve approximating the Silicon Valley-type of firm. That is to say, the ASO should develop some forms of hierarchies in order to coordinate the growth and the probably vertically connected integration; the external linkages always remain very important as they allow the flow of external knowledge into the firm and allows the firm to respond to the changes in the environment.

In this phase ASOs already developed a first product of success in terms of revenues which allowed them to reach the point of credibility. In our sample of relatively new firms, we identified four firms out of ten reaching this phase. The other six firms did not get to this phase due to two main reasons: One reason is the relatively young existence of the ASO and therefore the exploited product did not yet produced enough revenues to make the firm move further along the ASO life cycle, while the second reason is given by the inability to get to the credibility threshold despite having been on the market for sufficient time. This last group of firms lacked some of the fundamental capabilities enabling the passage to the next phase. For example, one of our firms, configuration $t_{0,1}$ evolved in $t_{1,1}$, despite the diversification strategies undertaken, explains the difficulties in developing a sufficient level of market knowledge:

“We continue in developing beautiful and highly innovative ideas: Companies remain astonished from our ideas, but it’s not enough. We produce high technical contents, but companies also look for proofs of feasibility, information about market potentiality, expected revenues and further development costs of the product. We should start from these steps even before starting the development of the research idea. We lack this approach. We are all scientists. I’ve really spent lots of effort in order to acquire managerial capabilities that I didn’t have, but I remain a scientific background figure. I still lack some tools.”

This firm develops R&D packages, related to the chemical, pharmaceutical and natural (cosmetics and agro-alimentary) sectors. The products of their business activity are mainly molecules that revealed to be highly fungible (an indivisibility character), that is with many different applications. The property of fungibility of the knowledge to be exploited requires the development of a high level of downstream capabilities (Antonelli 2006), and the commitment of the commercial function just on the previous network both at the time T_0 and

T_1 could represent a possible reason of failure in getting to the point of market credibility. Moreover the firm is getting to its sixth year of life, and by University's regulation ASOs can remain within the university locality for no more than six years after its generation: Firms' plans are to move out the university laboratories just with the natural sector related activities, losing or going to outsource the other sectors activities, the ones on which the firm used to build the business. In other words the firm seems to move back to the beginning of the pre-organization phase with the new narrow business activities.

Three configurations distributed amongst four firms approach the T_2 time. Two of these configurations are very similar: Configuration $t_{2,12}$ and $t_{2,13}$ differs just in the R&D function, where the first configuration represented by one firm relies more on the outside knowledge than the other configuration composed by two ASOs. The reasons for this difference is mainly due to the core activities of the two groups of firms: While $t_{2,13}$ group is formed by designing-manufacturing based enterprises, the firm displaying configuration $t_{2,12}$ is a service based venture (at T_1 the R&D function is absent), and the level of R&D is comparatively low. At time T_2 the firm is participating in the development of a physical instrument in conjunction with a local firm that own an important share of technical but above all designing capabilities.

Table 3: Governance of knowledge in the different functions at Time T_2

	$t_{2,12}$	$t_{2,13}$	$t_{2,14}$
R&D	L	H	H
Prod.	H	H	H
Comm.	L	L	L
Training	H	H	L
IP	L	L	H
Gover.	H	H	H
Firms no.	1	2	1

From this table it is noticeable that $t_{2,13}$ and $t_{2,14}$ configurations are identically structured for the R&D, production and commercial processes, where R&D and production are internally based while the commercial function is related to the knowledge available in the environment. The IP issues are entrusted to external knowledge in all the cases apart from one firm, where an internal function of IP screening has been undertaken recently. This firm (previously in configuration $t_{1,10}$) experiences a very deep organizational structure change from time T_1 to time T_2 : All the functions appear changed. The R&D and the productive function became internally coordinated: We can notice that the development and the growth of the ASO produced a sort of financial dependence of the research centre on which the firm generated.

The ASO nowadays finance the major part of Ph.D. and *post-doctoral* students working in the research centre. The commercial function has become a specialized function of the firm, mainly carried out by the institutions of a fund-raising division, and more than one human resources is dedicated to this role:

“Next and transversal to the three organizational divisions the fundraising. [...] It has been developed over time. [...] We really like the fund-raising mechanism and the European projects system functioning”

The training of employees showed a curious evolution, from external in T_0 to internal in T_1 , to again external in T_2 : Initially the research centre was the main training source for the ASO employees, while the ASO itself took care of the function during the pre-organizational phase where the main assumptions were directed toward the R&D and designing processes more than the manufacturing productive processes, and where internal interactions are fundamental in order to develop ideas and invention around two very far subjects. In the new phase, where the main R&D and productive routines are settled, the assumptions are all moved toward a unique source of formation, the mechatronic faculty, where the graduated have mechanics, electronics and informatics competences. The relevance of the availability of these professions appear to be significant in order to consider the knowledge governance of this functions more external. The presence of these figures also determines an internal productive process development:

“Next to the software and services, an increasing production of hardware prototypes is taking place. Previously we used to refer to the market for all the components: Suppliers were easy to find. Since early 2008 we adopted the politics of making things internally. This choice is mainly due to the increased mechatronic competences within the firm across the years.”

Firms of configuration $t_{2,13}$ didn't undertake vast changes in the passage from T_1 to T_2 : One of them changed the governance of two functions (production and commercial function), whilst the other changed the governance of only one function (commercial function). What concerns the two firms of group $t_{2,13}$ is the fact that the productive function has been kept internal for one firm, where as the other moved from an external to an internal governance. The reason of this shift is given by the development of specific hardware requiring the intervention of co-specialized complementary asset owners, that is the transfer of knowledge from the ASO to these complementary firms. The commercial function, on the other hand, moved from an intermediate level, that is based both on the previous network and on some specialized

professions within the firm connected with the environment to just a specialized arrangement, in both firms. The workshop firm example is again exemplificative of this decrease of importance of the previous network: Reiterating a previously quoted passage of an interview, this firm's CEO said:

“So far, we organized four editions of this workshop: The first two editions at a national level, and the second two at an International level. This activity acted as a showcase for us: After the first workshop we activated two more pharmaceutical clients, who committed parts of research they were conducting to us. Then we experienced an exponential growth: Now we work for 25-30 companies, mostly pharmaceutical, one in Emilia Romagna, 60-70% in Italy and the rest abroad.”

The overall tendency toward a centralized governance of knowledge is clarified by this firm's example, one of the $t_{2,13}$ configuration: The firm at this stage, already developed its first successful product, which create a strong positive signal in the sector. A few years after the success obtained by the first product a new product was to be launched. The new product development took place with *ex-novo* designing and manufacturing processes and a service function complementing the product exploitation. The product had greater success than the first product, with the consequent growth and expansion of the firm. Between 2003-2004, the expansion of the firm required an organizational change in order to be able to manage this expansion: Mainly by hierarchies introductions and internalization of business activities. Two main specific figures came into the firm during these years, representing in our opinion on one side a generation of hierarchies and on the other side a process of internalization of the productive function and of the overall governance of the knowledge function. The first one has been hired in order to give a more serious organizational structure to the firm: The function of R&D, Service, Design, and Production have been identified and some internal regulations have been set. Although still low, more structured hierarchies started to take place. Later on, in the beginning of 2006, the main figure involved in the commercial function left the firm and a new expert figure had to be hired with the function of coordinating the feedback from the market to the R&D and designing functions. This employee had 25 years of experience in a one of the largest Italian manufacturing corporations, and represents nowadays the most *mature* figure of the firm:

“I brought into the company order and decisional rationality: What we shall realize within the firm and what we get from outside, understanding when a prototype is ready, that is when it is the case to go further in its development or to stop. [...] Creativity is outstanding.

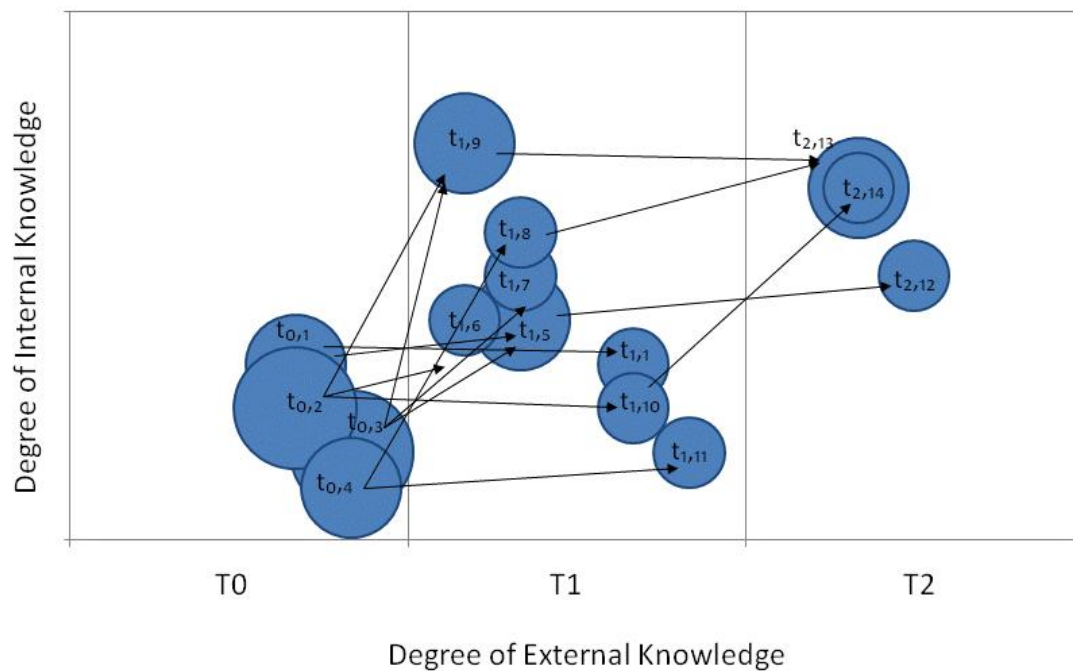
Everyday someone get to a new idea: It is important to put them in a row, and understand whether they are part of the core business or not, and which ones are to be continued.”

The productive function became more internally managed because of the co-specialized complementary assets required to the new ex-novo designing and manufacturing processes. Moreover, the productive function, in the case of the service department, is heavily connected with the upstream R&D and designing process, enabling feedback to work within the firm. The efficiency of this feedback flow has to be mainly given to the new experienced hired figure.

The firms' configurations at time T_2 appear to be quite similar, as said, where the upstream functions are mainly based on internal resources and capabilities, whilst the downstream market knowledge still requires a high level of external linkages. The fact that upstream functions are mainly developed internally does not mean the upstream linkages are not important, but simply that the new knowledge generation is mainly based on internal routines and capabilities, where downstream functions are mainly based on knowledge external to the firm. The variety of the configurations that arrive to time T_2 clearly indicates a convergence towards similar ways of managing the governance of knowledge around the boundaries of the firm, but as we noticed, the paths in order to get to this point are highly different, and depending on high level of idiosyncrasies as showed in the qualitative analysis.

Let us now summarize the foregoing discussion by providing a heuristic synthesis of the developments that we discussed so far. With respect to the literature we surveyed this diagram – developed only for illustrative purposes – represents a further articulation of Vohora et al. (2004) ASOs' life cycle (figure 1): It shows the typologies of organizational structure in terms of the ratio between internal versus external knowledge governance of each ASO of our population at the three studied phases of its life cycle.

Figure 2: Knowledge governance evolution in Emilia Romagna ASOs' life cycle



The figure highlights the variety of paths in which each organizational structure evolved from T_0 to T_1 , and the selection process that reduced the typologies of organizational structures getting to T_2 . More broadly it is an illustrative explanation of the dynamics taking place in the processes by which a stand-alone laboratory grows to become a Silicon Valley-type of firm. In other words it offers a further step in Teece's analysis of firm organizational structures, with a specific orientation in the context of ASOs. The next section will provide a synthesis and conclusion of the findings of our work.

4. Conclusions

This work has sought to analyze the development paths followed by ASO firms throughout their life-cycle. It has been noted that on the one hand the ASO's organizational structure in an early stage of the cycle resembles the stand-alone laboratory of Teece's (1996) taxonomy; on the other hand the description provided by the academic literature refers to a Silicon Valley-type of firms. Our research has sought to fill the gap between these two extremes and to describe the paths that an ASO follows from one archetype to the other. We investigated

the issue by looking for whether some basic functions were conducted mainly internally or externally to the firm; in other words we tried to capture the prevalence of internal versus external modes of knowledge governance adopted by a firm to undertake some fundamental business activities at different stage of the ASO firm development, with the two extremes being the stand alone laboratory versus the Silicon Valley-type of firm.

The empirical analysis on a selected sample of ASOs firms shows that at an early stage few organizational configurations are possible. These are quite similar in that they share decentralized knowledge governance similar to the stand-alone laboratory. This resonates with the notion that a new firm needs to be deeply connected to the environment in order to be able to coordinate the useful knowledge required for operating in the market place with the external environment. While upstream linkages with the parent organization are strong at the beginning, downstream linkages need to be developed during the life cycle. These linkages are very important because of the knowledge's tacitness the ASO firms typically try to exploit. The tacit character, in turn, reduces appropriability and requires the development of entrepreneurial capabilities in order to be transferred. The academic entrepreneur therefore is an intermediary in scenarios with high transaction and interaction costs. In some cases of the population studied, horizontal complementary assets were also needed, and when specialized or co-specialized, other agency issues have to be addressed. The deeply connected environment of Emilia Romagna and the supporting tools provided by the region are conducive to reducing transactions, networking and communication costs. The development of downstream and horizontal linkages is crucial in the development of the ASO firm and sometimes some of these activities are internalized by firms. The Silicon Valley-type of firm prototype is reached by less than half firms of our population at the end of the life-cycle. These firms show a low variety of structures, basing their activities mainly on internal knowledge governance, therefore showing some level of integration and hierarchy.

In order to get through the entire life-cycle firms must overcome some critical steps (Vohora et al. 2004). One of them is a credibility threshold in the passage from early to established firm (T_0 to T_1 pointing our language). The empirical work indicates a variety of different paths in terms of organizational structure, that is in terms of knowledge governance that have been followed by the different ASOs over their life cycle. In other words the empirical work conducted here refutes the notion that the transformation of a stand-alone laboratory into a Silicon Valley-type follows a dominant, or unique, route. Rather, the factor bias of each firm shapes a specific path of growth and development, and for the entire population these are

likely to be different and at times overlapping, paths. Finally and most important, not all firms reach a mature stage in the life cycle; for those that do, we observe a reduction in the variety of organizational structures. In other words it appears that ASOs undergo some kind of selection processes.

Both the beginning and the end of the stylised life cycle therefore feature a relatively lower variety of organizational knowledge and of governance structures: The same Penrosian resources at the two points in time, differently combined in terms of internal versus external knowledge, entail different organizational structures. Our work therefore adds to the framework elaborated by Vohora et al. (2004) on the development paths of ASOs: By proposing a richer articulation of the development paths that are possible in the firm life cycle.

Conceptually the present work also speaks to the theory of the firm by arguing that it is necessary but not sufficient to focus either on transactions or on resources. The integration of the two main strands of literature on the theory of the firm indicates that the adoption of a framework that uses knowledge governance as a unit of analysis is a fruitful line of investigation. If we recognise that the same blueprint applied to two different contexts (also different firms of the same local environment) lead to different outputs, it means acknowledging the centrality of learning in the innovation processes, and therefore it means implicitly recognizing that knowledge is a dynamic resource that changes as soon as it is applied in a specific context of use. If we further assume a dynamic perspective in order to understand the innovation processes, and therefore the drivers of economic growth and development, the governance of knowledge has to take centrality in the analysis of the firm. This work follows the steps indicated by Antonelli who stressed the importance of focusing on knowledge governance in order to appreciate the component processes of technological change. While previous theories of the firm concentrated on large-manufacturing corporations, this approach opens up more flexibility to include a broader range of organizations and firms, not least KIBS, and contextualizing them in their localized environment.

We studied how knowledge is organized inside a particular type of firm at different stages of development. The same approach could be applied to different contexts and different typologies of firms, and could lead to a better understanding not of the boundaries of the firm, but of the knowledge organizational mechanisms undertaken by a firm.

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