

Commercialisation strategies of research-based spin-offs: the case of companies that operate in the market for technologies¹

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Abstract

This paper addresses the conditions in which research-based spin-offs (RBSOs) conduct their role in the transformation of scientific and technological knowledge in economic value, focusing on their commercialisation strategies. We discuss the conditions that can influence/constrain firms' ability to pursue with different strategic orientations and advance some hypothesis regarding key factors that are likely to determine their strategic choices: nature of knowledge being exploited, appropriability conditions, location and degree of control upon critical non-technological assets, institutional setting of origin. Particular emphasis is put on one specific strategy: selling or licensing the technology (as opposed to embodying it into products or services), which is becoming increasingly widespread in some fields and which, we contend, RBSOs may be more prone to adopt, due to their specific characteristics. These hypotheses are tested on a group of 80 RBSOs from 6 European countries, using data collected specifically for this purpose, on the basis of questionnaire-based interviews.

This research adds to recent work on the determinants of the commercialisation strategy of technology-based SMEs, but by focusing on a particular group of companies - the RBSOs – we also take in consideration some distinctive characteristics of this group, which introduce some specificity in their innovative behaviour.

¹ Support from the PICO project (“Academic entrepreneurship, from knowledge creation to knowledge diffusion”, contract n° 028928) sponsored by the Sixth Framework Programme of the European Commission is gratefully acknowledged. The authors would also like to thank the other members of the PICO team for conducting data collection on RBSOs in their respective countries, as well as for their contribution to various debates around this paper.

1. Introduction

Research-based spin-off companies (RBSOs) have for some time been regarded as an instrument for the commercial exploitation of knowledge produced in public sector research organisations (Wright et al, 2007). However, RBSOs are heterogeneous companies, created in a diversity of conditions and displaying a variety of behaviours (Mustar et al, 2006) and this variety has implications for the role(s) they play in the transformation of scientific and technological knowledge into economic value.

This research is concerned with one potential source of heterogeneity – the commercialisation strategy adopted by the RBSO. By definition, RBSOs are firms set-up to exploit scientific and technological knowledge developed in academic research (Mustar et al, 2006). In order to pursue with this goal, the new firm has to make a key choice regarding the mode of capturing value from its knowledge assets. It may opt for engaging in the development of products or services based on its knowledge/technology; or rather opt for selling or licensing the actual technology (Gans and Stern, 2003). The decision on the commercialisation mode is a major strategic choice for start-ups (Arora et al, 2001), which can have an “imprinting” effect (Eisenhardt and Schoonhoven, 1990) and that is conducive to different modes of behaviour - concerning the organisation of firms’ innovative activities, the outcome of these activities, as well as the way firms interact with their environment – thus leading to heterogeneity in terms of the functions that RBSOs play in the innovation system.

To engage in the development of products or services and bring them to the market, alone or in alliance with other firms, is the most typical strategy. However, the case of companies that specialise in the production and sale of intellectual property, is becoming more frequent, particularly in some fields, as markets for technology develop (Chesbrough, 2006; Cesaroni, 2004). But it remains a relatively less understood phenomenon. In this paper we address the strategic decision made by RBSOs regarding the mode of commercialisation of their technology, focusing specifically in the decision to target the market for technologies, as the firm main business.

Drawing on two main theoretical sources - the economics of technological change and the strategic management of technology – we build a conceptual framework whose starting point is the notion that the main asset possessed by RBSOs is their technology and that, therefore, firms’ decisions will be mainly influenced by two types of factors: those related with the technology and the nature of knowledge underlying it (Malerba and Orsenigo, 1993) and those related with conditions that enable firms to capture the value from their technology (Teece, 1986). Combining insights from these streams of literature with those from previous research on the behaviour of new technology-intensive firms, we identify a number of factors - nature of the knowledge being exploited, appropriability conditions faced, firms’ access to and level of control upon downstream complementary assets, institutional setting they originate from - that influence (or constrain) RBSOs ability to adopt this type of business orientation, and formulate a number of hypotheses regarding their impact upon RBSO strategic decisions. These hypotheses are subsequently tested on a sample of European RBSOs.

2. Commercialisation strategies of RBSOs

RBSOs strategic decision on how to transform the knowledge developed in a research organisation into economic value, also entails a decision on the type of market to target in order to capture the value from that knowledge: so firms can opt for trading exclusively in the

market for technologies, or chose to trade in the market for products (Arora et al, 2001)². The requirements for operating in each type of market are expected to be different (Gans and Stern, 2003) and thus, in order to explain the decision made by the RBSOs, it is necessary to understand the conditions that enable start-up firms to comply with these requirements.

The focus of this research is on companies that target the market for technologies – that is, markets where technology is traded in the form of intellectual property (IP) or other intangible forms, rather than embodied in products or processes (Arora et al, 2001). The option for trading in intellectual property assets – and particularly for doing it as the main business and not as a complementary or a transitory activity, while the core product or service is being developed - has been an exception, until recently (Teece, 2006). However, we observe an increase in the number of companies that adopt this strategic orientation (Chesbrough, 2006; Pries and Guild, 2007; Hicks and Hedge, 2005).

The wider generalisation of this strategy was triggered by changes in the institutional setting, namely in the organisation of the academic system, the division of labour between private and public organisations, the intellectual property rights system and the financial system (Coriat et al, 2003; Antonelli and Teubal, 2008; Argyres and Liebeskind, 1998; Bekkers et al, 2006; Wright et al, 2007). These changes enabled extensive patenting of results of public research and encouraged company formation to exploit them, leading to the emergence of firms that perform basic research, appropriate its results through patenting and whose assets are IPR instead of products or services, but who are able to obtain capital on the basis of the value attributed to that IP. The expansion of markets for technology – triggered by the strengthening of appropriability regimes and by the changes in technology strategies of large firms – created growing opportunities for these research-based firms, enabling them to co-exist with established firms, to whom they act as specialised suppliers of contract research and basic technologies (Arora et al, 2001; Chesbrough, 2006; Cesaroni, 2004). While the bulk of these changes took place in the life sciences field – where the proximity between scientific research and application were particularly favourable to these changes - it is argued that the same rationale is starting to apply to other sectors (Coriat et al, 2003).

Despite some recent interest in this phenomenon (Bekkers et al, 2006, Hicks and Hedge, 2005; Kollmer and Dowling, 2004), the conditions that are behind the emergence of these firms and that sustain their development are still relatively less understood, which makes them a relevant object of analysis. The particular case of RBSOs is even less explored: while some authors have described spin-offs' business models that fit within the technology trade strategy (e.g. Stankiewicz, 1994; Druilhe and Garnsey, 2004), attempts to explain this type of commercialisation strategy are rare (Pries and Guild, 2007). However, RBSOs may be particularly prone to adopt this strategy, not only because the nature of the knowledge they are exploiting may favour it, but also because it may be cognitively closer to the founders' identity as researchers and to the cultural environment they originate from.

In fact, RBSOs genesis as companies created to exploit scientific and technological knowledge originating from academic research, endow them with some distinctive features. RBSOs are more likely to apply scientific knowledge, whose characteristics may influence the conditions in which such exploitation takes place (Jong, 2006; Shane, 2001): it is

² Firms that engage in product development may also chose to sell/license (part of) their technologies, for various reasons (Lichtenthaler, 2008), although this option is less likely in resource constrained start-ups. These may nevertheless engage in some technology trade activities, while developing the core product (Kollmer and Dowling, 2004).

potentially more novel, more easily codifiable and more generic, thus generating a wider set of opportunities, but also being more distant from applications. RBSOs are created by entrepreneurial teams that usually involve at least (or exclusively) some of the academic scientists or engineers who developed the technology (Murray, 2004). Thus scientific and technological competences and networks, are likely to be prevalent, even if some teams integrate individuals with managerial experience (Ensley and Hmieleski, 2005). Finally, RBSOs originate from a non-commercial environment, which not only may have culturally shaped the individuals involved in their creation, but can also exert (directly or indirectly) some influence upon the type of decisions made at start-up, while being less likely to provide support in the access to non-technical competences and resources (Clarysse et al, 2005).

These specific features are expected to shape the new organisation at three main levels: the nature of the technology being commercialised; the type of competences and resources possessed by the founders; the level and type of intervention of external actors, and thus contribute to influence their decision making process.

3. Factors influencing RBSO decisions on commercialisation strategy

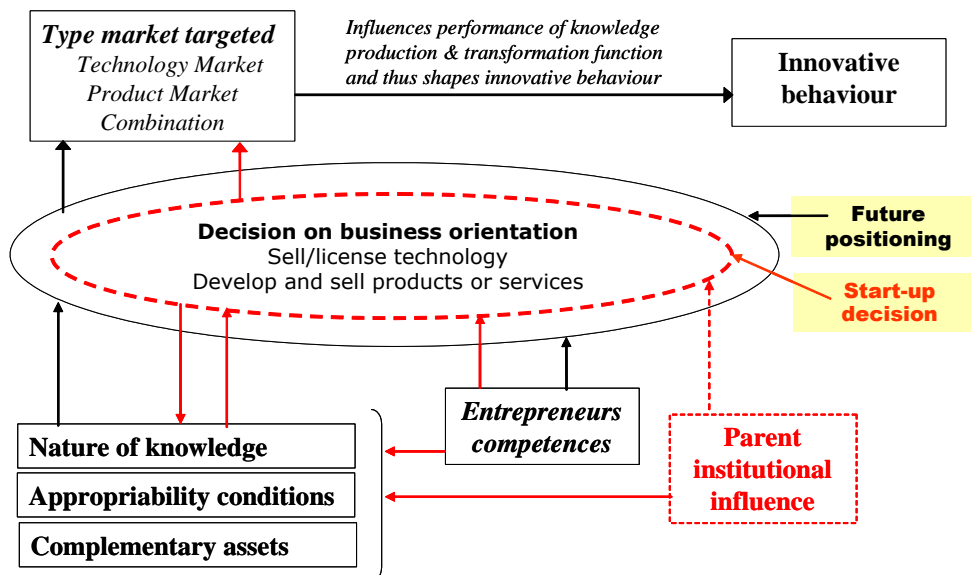
Our approach to the factors that influence RBSOs decision on the commercialisation strategy combines insights from two main theoretical sources: the economics of technological change and the strategic management of technology. Drawing on these streams of literature we build a conceptual framework whose starting point is the notion that the main asset possessed by RBSOs is their knowledge/technology (Shane, 2001) and that, therefore, firms' decisions will be mainly influenced by two types of factors: a) related with the technology and the nature of knowledge underlying it – i.e. with “technological imperatives” (Malerba and Orsenigo, 1993); b) related with conditions that enable firms to capture value from their technology (Tece, 1986).

More specifically, we propose that the “technological imperatives” associated with the nature of the knowledge being exploited, and the respective economic implications, are likely to have a strong impact upon - and thus condition/shape - the strategic orientation pursued by the RBSO. But, since the capacity to profit from innovation requires going beyond the sole consideration of those “technological imperatives”, we also propose that the nature, location and mode of deployment of a set of non-technological competences and resources, will equally influence the RBSOs' strategic orientation. In addition, considering that RBSOs are companies that originate from a public sector research environment, we also propose that some features of that environment (and its potential imprinting effect upon the company) are likely to influence firms' strategic orientation, namely through their impact upon the above mentioned dimensions.

Thus, we advance the general hypothesis that RBSOs decision regarding commercialisation strategy is influenced by four types of factors: 1) nature of knowledge being exploited; 2) appropriability conditions, i.e. capacity to protect the technology; 3) location and control of critical non-technological assets, described in the literature as “complementary assets”; 4) academic institutional setting (particularly relevant at the start-up stage), expressed through the direct or indirect influence of the parent organisation and through the impact of founders background upon the firm early competence base.

We also advance that these factors may impact differently upon the early decision to target a given market and upon the ability to operate in that market (at a steady state) as the firm main business. Figure 1 depicts graphically this conceptual framework.

Figure 1 – RBSOs decisions on commercialisation strategy



In the next sections we present in detail the theoretical foundations of this framework and formulate several specific hypotheses regarding how these factors influence the commercialisation strategy of RBSOs, with particular emphasis on their influence on the decision of targeting or not the market for technologies.

3.1 Evaluating the nature of the key asset: factors related with nature of knowledge

In order to address the impact of factors related with the technology being exploited and the nature of knowledge underlying it, upon the commercialisation strategies of RBSOs, we draw on the economic theory of technological change and particularly on the approach introduced by the “technological regime” framework (Nelson and Winter, 1982; Malerba and Orsenigo, 1993). This approach is exactly concerned with the relationship between firms’ behaviour – that is, strategies and forms of organisation - and the technological environment where these firms operate, which, it is argued, sets the boundaries of firms' problem solving activities and establish the trajectories along which innovation can take place (Nelson and Winter, 1982). Thus, the behaviour of a firm will be shaped and constrained by the properties and dynamics of the knowledge underlying the technologies it develops/uses (Dosi, 1988).

Malerba and Orsenigo (1997), drawing upon Dosi (1988) description of the dimensions that characterise a technological regime, operationalise it as a combination of some fundamental properties of technologies: opportunity and appropriability conditions, degree of cumulativeness of technological knowledge and characteristics of the knowledge base, which include: levels of pervasiveness/specificity, tacitness and complexity. Opportunity is defined as the ease of innovating for a given investment in search for new solutions; appropriability as the possibility to protect innovations from imitation; cumulativeness as the extent to which

current innovative activities are based on knowledge and innovations developed in previous periods (Breschi et al, 2000). These properties provide an important analytical device that enables us to address the nature of the technologies being exploited by RBSOs.

3.1.1 “Technological imperatives” and their impact on firm behaviour

At an empirical level, the influence of the technological environment as a determinant of firms innovative behaviour has generally been addressed at the macro level. Basically, researchers have provided generic characterisations of innovative behaviour at sector/industry level, associating it with the prevailing technological regimes (e.g. Breschi et al, 2000; Klevorick et al, 1995; Evangelista and Mastrostefano, 2006; Marsili, 2002). These analyses offer some insights into the potential behaviour of firms according to the industry where they are located, providing a generic idea of the environment where they are operating, but have a limited application when we intend to address strategic decisions at the level of the individual firm (Leiponen and Drejer, 2007). This suggests that we need to go back to the theoretical discussion of the fundamental properties of technology and try to understand their implications for the strategic behaviour of young technology intensive companies.

Malerba and Orsenigo (1993) discuss the opportunities and problems derived from different combinations of the basic properties of the technology, as well as their outcome in terms of the “menu” of viable technology strategies. Despite its generality, their “matrix of basic technology strategies” can provide some guidelines towards the options open to firms subject to different conditions. Considering that RBSOs are new entrants endowed with an advanced technology, we will use as starting point the generic strategy “exploration of new technologies”, which corresponds to the basic function performed by these firms. Following Malerba and Orsenigo (1993), this strategy is always associated with *high opportunity* conditions, but can be associated with different combinations regarding other properties, since cumulateness and appropriability can be high or low.

High level of opportunity is viewed as an incentive for innovation and thus potentially offers good prospects for new entrants. But the sources of technological opportunity differ (Klevorick et al, 1995), which influences the chances of these entrants (Marsili, 2002). Since RBSOs are created to exploit new technological opportunities derived from academic research, it is expected that scientific advances are their main source of technological opportunity, as opposed to technological advances originating from the industry. Knowledge originating from outside the industry – as is the case of the one originating from academic research - is likely to be less industry-specific and less cumulative and thus, when this type of knowledge plays a more important role as source of opportunity, new firms tend to have an advantage (Winter 1984). Rather, when knowledge generated within the industry prevails, high opportunity may be associated with high cumulateness, favouring exploitation by established firms (Marsili, 2002). In both cases, if appropriability is low, imitation by followers is a possibility and thus the strategy has to be coupled with alternative strategies of strengthening appropriability. However, the latter may be beyond the reach of small entrants, to whom formal appropriation mechanisms are often the only effective means of protection (Hall, 2005).

High technological opportunity is often associated with high pervasiveness, i.e. the possibility of using the same core knowledge in a variety of applications (Malerba and Orsenigo, 1993). Since pervasive knowledge offer opportunities for diversification through its application to

diverse products and markets, it can be advantageous for new entrants. This is particularly the case if cumulateness is low, but in conditions of high pervasiveness, cumulateness may not be a deterrent for new entrants, since diversified and specialist firms, occupying different niches, may co-exist in the same industry, by adopting a different (and often complementary) strategic positioning, as the cases of biotechnology and more recently nanotechnology amply document (Orsenigo et al, 2001; Zucker et al, 2007)

Thus, globally, conditions of high technological opportunity, particularly when associated with pervasiveness, high appropriability and low cumulateness appear to be the most favourable for new small entrants exploring new technologies; even if it is also possible for these new entrants to survive under other combinations of conditions, which still enable this type of generic strategy, but are more favourable to incumbents, thus requiring the new firm to find ways to co-exist with them.

3.1.2 Research on the influence of technology characteristics on strategic decisions

The impact of the nature of technology upon the strategic decisions of technology intensive companies has been addressed by few authors. For instance Shane (2001), looked at the impact of several attributes of new technology (patented inventions originating from academic research) upon its exploration through new firm formation as opposed to incumbents. He found that the exploration of more important (measured through the invention's economic value), more radical and broader inventions was more likely to be conducted through a new firm. Nerkar and Shane (2007) stressed the attributes of technological inventions that affect appropriability, arguing that the technology base has more impact upon performance of technology-based firms than managers' strategic choices.

Hicks and Hedge (2005) studied firms with "sustained technical relevance" (measured in terms of patent record) and found that small patent-based specialist suppliers that manage to survive and have long lasting success in the markets for technology, develop technology that is more general purpose, has a broader range of applications, has higher quality and is also more basic and closer to science. Similarly, Gambardella e Giarratana (2007), drawing on Bresnahan and Trajtenberg (1995) analysis of general-purpose technologies, concluded that the presence of these technologies favour technology trade, and thus that they are more likely to be licensed. Conversely, the generality of the technology can have a negative impact on new product development because it makes it less suitable for specific application, and thus can be a deterrent for entering in product markets.

3.1.3 The impact of nature of knowledge on RBSOs strategic decisions

The limited consideration of the impact of the nature of knowledge upon the commercialisation strategies of new technology intensive companies, associated to the importance of this asset for RBSOs and the potential for heterogeneity at this level, led us to give particular attention to this issue in our research. On the basis of the above discussion on technological imperatives and their impact on firms' behaviour, we formulate some hypothesis regarding the influence of this specific factor upon RBSOs strategic decisions.

The discussion suggests that more general purpose (or pervasive) technologies can provide firms with a "platform technology" that supports a continuous stream of development. This can be critical for firms that intend to operate in technology markets (TM) in a sustained way. On the other hand, more generic technologies also tend to be more distant from applications

and thus to be more difficult or take longer to convert into products, thus being a constraint to operate in product markets (PM). Therefore:

Hip 1a: *RBSOs in TM are more likely to have pervasive technologies than RBSOs not in TM*

In addition, technologies with a greater component of new knowledge can be more valuable for potential acquirers and thus offer a competitive advantage in the TM. Given their novelty they also have a greater possibility of being patented, as well as to provide more valuable patents (Shane, 2001), which is equally important when operating in TM.

Hip 1b: *RBSOs in TM are more likely to have technologies that involve a greater component of new knowledge than RBSOs not in TM*

The impact of the parent organisation on the nature of knowledge being exploited should also be taken into consideration. New scientific knowledge – particularly the one associated with more basic research - tends to be generic in nature, enabling the opening up of a variety of search trajectories (Saviotti, 1998). Since knowledge developed in the context of academic research is more likely to originate from basic science and is also more likely to be closer to the knowledge frontier, RBSOs that exploit technological knowledge mostly developed in the academic context are more likely to have technologies that are more generic, more novel and more related with basic principles (and thus more distant from applications), as compared with those in which technological development was mostly conducted already in the new firm, on the basis of founders' (tacit) knowledge. Therefore:

Hip 1c: *RBSOs in TM are more likely to start-up with technologies developed in the context of the parent research organisation and transferred to the new firm, than RBSOs not in TM.*

Finally, since RBSOs technological competences are largely embodied in the founders, the academic level/field of training and the type of technological experience and networks possessed by the entrepreneurs can also be regarded as contributing to the nature of technological knowledge present in the firm and thus have an impact upon the type of orientation pursued (Ensley and Hmieleski, 2005). Academic scientists differ in terms of degree of exposure to non-academic environments, but it can be generally argued that RBSOs that only have founders with academic research experience, as opposed to technological experience in industry, will be more likely to prefer to engage in research activities and build a technological portfolio, rather than to engage in the activities required to transform that technology in products, which require different skills (Dasgupta and David, 1994).

Hip 1d: *RBSOs in TM are more likely to be created by founders whose technological backgrounds are exclusively academic, than RBSOs not in TM.*

3.2 Capturing value from the technologies

Despite the critical importance of the knowledge/technology asset, the transformation of technologies into products and their commercialisation requires the consideration of other aspects that are instrumental in enabling firms to capture the value from their technologies. While some of the properties of technology introduced by the technological regimes literature – e.g. appropriability and cumulativeness – already incorporate this dimension, the focus of this literature is not on that specific problem. This question has been addressed in greater

detail by the strategic management of technology literature and particularly by the branch that focus on the markets for technology (e.g. Arora et al, 2001; Gans and Stern, 2003).

3.2.1 Contributions from literature on markets for technology

The literature on markets for technology draws a great deal on Teece (1986) seminal approach to the alternatives and also the hazards faced by firms in the introduction of their innovations in the market. The key dimensions of Teece analysis – the appropriability conditions and the nature, location and mode of deployment of a set of specialised non-technological competences and resources, that cannot be easily acquired in the market but are needed to capture rents from the innovation, labelled “complementary assets” – are retained as the basic analytical structure. One important contribution of Teece approach was to link the discussion on appropriability to that on complementary assets, since the latter can be both part of a strategy for strengthening appropriation when appropriability is low, and a mechanism through which incumbents capture a substantial part of the value from technological innovations. Following Teece, the combination between these two factors is at the root of the most recent research on the conditions faced by young firms commercialising new technologies. However, these approaches move beyond Teece, by proposing that, in some conditions, it is possible for (small) innovating firms, to avoid the ownership of specialised assets and still capture rents from their innovations, due to the development of the markets for technology.

One important contribution of this stream of literature to our question, concerns the impact that the development of markets for technologies had upon the *alternatives open to small technology intensive companies*, namely by creating new forms of division of inventive labour (Arora et al, 2001). Large technology advanced companies increasingly tend to focus on their core R&D competence and to acquire technology developed by other companies in less strategic areas, creating conditions for the emergence of firms specialised in research and technology development, that act as suppliers of intellectual property (Antonelli and Teubal, 2008). Thus, the functioning of markets for technology increase the effectiveness of strategies associated with specialisation in the trade of technologies as opposed to products, creating opportunities for firms that adopt this specific positioning (Arora and Merges, 2004). These firms can opt for focusing on developing the technology and thus avoid incurring in the costly development of manufacturing and commercialisation facilities and competences. The presence of markets for technologies enable them to resort to licensing or other technology trade agreements to capture the value of their development efforts. However, this option also have hazards, particularly for small firms with low bargaining power in contracting and limited capacity to uphold expropriation threats by dominant companies. Thus, the choice for the more adequate strategy should always balance these hazards against the situation in the markets for downstream assets, since the conditions in these markets may lower the costs of the acquisition of some of them (Gans and Stern, 2003).

3.2.2 Research on commercialisation strategies of technology intensive firms

In contrast to what was remarked above regarding the nature of knowledge, the impact of appropriability conditions, and also, more recently, the combined impact of appropriability and complementary assets upon the commercialisation strategies of technology intensive firms, has been extensively discussed in the literature.

The most comprehensive analysis was conducted by Gans and Stern (2003), who developed a conceptual framework to address the decision process of technology-based start-ups. They address the conditions in which new firms should compete directly in the product market with established firms; and those in which they should adopt a cooperative strategy, entering into agreements with those firms, which then become the channel to move the technology into the product market. One key aspect of this approach is that it explicitly considers the possibility that established firms both control key complementary assets and have an incentive to appropriate the innovation, which make alliances with them potentially more risky. The drivers behind the choice are, therefore, the capacity to preclude imitation by incumbents and the extent to which incumbents own complementary assets that contribute to the value proposition of the technology, and the authors discuss at length the conditions that favour cooperative and competitive strategies. Gans et al (2002) examine empirically this issue and their main finding is that a cooperative strategy (operationalised as selling the technology or the firm to incumbents) is more likely when new firms control the intellectual property rights. However, control over complementary assets was not found to have significant impact.

This issue was addressed empirically by other authors, who looked at patent-based SMEs and considered the range of strategic options open to them and, in some cases, put forward factors that may determine these strategies. Giuri and Luzzi (2005) built a taxonomy of strategies that distinguishes between firms that develop and sell the technology as a disembodied good (market for technologies) and firms that integrate the technology in physical artefacts: either into intermediary technology inputs used by other firms to manufacture final products (market for embedded technologies), or in products sold in product markets. Analysing the strategies of patent-based European SMEs they concluded that the former was relatively less frequent. Novelli and Rao (2007) added US firms to the above sample and investigated the determinants of the commercialisation strategy - i.e. of the choice between directly trading on the technology vs. incorporating it in physical artefacts – focusing on firm characteristics. They concluded that ownership of complementary assets (operationalised as presence of manufacturing facilities) is the main determinant and that SMEs which lack complementary assets are more likely to license their technologies, although such licensing is more likely to be done by younger firms and thus can be an entry strategy. Finally, Pries and Guild (2007) addressed the commercialisation strategies of RBSOs. On the basis of a sample of Canadian spin-offs and using archival data they looked for the differences between firms operating in product and on technology markets, in terms of the business activities performed. They found that the former focus on both technology development and product activities, while the latter focus exclusively on technology development activities.

This research have put particular emphasis on identifying and delimiting a strategy that focuses on technology trade, and on distinguishing it from strategy(ies) that focus on product/service development. But while the distinguishing element between what can be generally described as “technology market” and “product market” strategies is always whether the technology is sold as a disembodied good or is incorporated in physical artefacts, the way the strategies are defined varies, depending on the approach adopted by the various authors to the type of relationship the firm establishes with the buyers of the technology and especially, the modes on which such incorporation takes place. In particular, the nature of the discussion on the role of specialised complementary assets depends on whether the emphasis is put exclusively on the in-house development of downstream assets, or whether the possibility of establishing agreements with their owners is also considered. In our view this is a non negligible issue. In fact, while the relevance of non-technological relationships for small technology-intensive firms has been extensively discussed (e.g. Colombo, et al, 2006; Baum

et al, 2000; Elfring and Hulsink, 2005), the insight offered by Gans and Stern (2003) about incumbents who have an incentive to expropriate the innovation calls our attention to an important point: whether or not it is possible to establish such agreements in *relatively advantageous conditions*, is likely to be a key element in firms' decisions about the commercialisation strategy.

Additional contributions come from the literature on technology licensing that discusses the conditions in which firms decide whether or not to license their technology, and how such licensing takes place. While most of this literature does not focus on start-ups, it is generally found that the strategies of small/young firms are diverse from those of larger established firms: the former are more likely to license and also to depend more on the level of IP protection and on the conditions in the market for downstream assets (Gambardella et al, 2007; Cohen et al, 2000; Arora and Merges, 2004; Arora and Fosfuri, 2003).

These various streams of literature seem to converge into the conclusion that the appropriability regime and the access to complementary assets (under various forms) are key elements in firms decision concerning the modes of technology commercialisation; and that small technology intensive firms – and especially start-ups – given their limited resources and reduced bargaining power are particularly vulnerable to conditions at these levels. They equally suggest that engaging on technology trade and avoiding the development of production/ commercialisation assets, can be a favourable strategy for new entrants endowed with strong technological competences. However, it also becomes evident that this strategy has quite stringent requirements, not only regarding the characteristics of the technology (e.g. novelty, uniqueness) but also regarding the strength of IP protection. The latter is critical to guarantee the ownership of the intellectual assets and therefore to enable their transfer to third parties, as well as to protect firms' from expropriation. It also has risks, derived from engaging in contractual agreements with powerful companies that may have an incentive to appropriate the technology. Given these risks and requirements, technology-intensive start-ups should consider carefully the circumstances surrounding the commercialisation process and the alternatives open to them.

Thus, in order to fully understand the conditions that influence the RBSOs decision process it is necessary to look in more detail into these aspects of the appropriability regime and access to complementary assets that are most relevant for this category of firms.

3.2.3 The impact of appropriability regime on RBSOs strategic decisions

The appropriability regime can be defined as the conditions concerning the protection of intellectual property assets against imitation, either through legal mechanisms (e.g., patents, copyright, formal non-disclosure agreements) or “natural” barriers to imitation, afforded by characteristics of the technology (tacitness, difficulty in reverse engineering) (Pisano and Teece, 2007). In general, higher appropriability conditions increase the likelihood that companies earn profits from their innovation. But appropriability levels differ between sectors and the appropriability mechanisms that are available and effective also vary (Hurmelina-Laukkanen and Puumalainen, 2007). In the particular case of patents, the literature has shown that their incidence and effectiveness is confined to a few sectors, with alternative protection methods being extensively used in the majority of industries (Cohen et al., 2000; Arundel, 2001). However, it has also been shown that the level of patenting, has increased substantially in recent years, with particular incidence in “complex product

industries” (such as semi-conductor, electronics or software) where patents were traditionally less used (Hall, 2005)

In this context, RBSOs may configure a particular group of firms, since they are more likely to commercialise knowledge originating from scientific research. This type of knowledge is, in principle, more abstract and codified (Saviotti, 1998) making patenting easier. On the other hand, knowledge associated with new scientific discoveries can have a high tacit component, derived from its very novelty, which endows it with “natural excludability” (Zucker et al, 1998). This can provide the firm with temporary protection against imitation, which is particularly important when formal mechanisms are not viable or are less effective.

While there is some debate about the means through which small technology intensive companies can protect their intellectual assets, there is more agreement on the literature about the case of small technology *suppliers*, who wish to sell or license their technology. Legal protection, namely through patents, is regarded as indispensable (Arora and Merges, 2004; Gans et al, 2002), even if it is recognised that these firms may find it difficult to withstand cases of litigation. In fact, strong IP protection through patents, not only defends the supplier from expropriation, but also facilitates technology trade, by lowering transaction costs for both suppliers and buyers (Gans et al, 2002). Thus, patents permit to overcome Arrow’s (1962) “paradox of disclosure”: since they afford legal rights upon the technology, they enable the supplier to disclose more detailed information on the technology to the potential buyer(s), without running the risk of expropriation. This possibility and the guarantee of quality provided by the presence of a patent, reduces the asymmetry of information that characterise transactions in technology markets, also limiting the search costs faced by the buyer (Gambardella and Giarratana, 2007).

The above discussion enables us to put forward some hypotheses concerning the impact of appropriability conditions on RBSOs commercialisation strategies. First of all it suggests that legal protection through patents is critical for RBSOs operating in the markets for technology. However, appropriability conditions and effectiveness of patents as a protection mechanism differ between industries, which means that the appropriability regime prevailing in a given industry will constrain the actual presence of markets for technology and RBSOs ability to operate in these markets. The entrepreneurs’ perceptions about the appropriability conditions in the industry segment where they are willing to operate may influence their choice of commercialisation strategy. Therefore:

Hip2a: *RBSOs in TM are more likely to operate in sectors where level of appropriability is (perceived as) higher than RBSOs not in TM.*

Hip 2b: *RBSOs in TM are more likely to have their technology protected by patents than RBSOs not in TM.*

It is nevertheless relevant to consider that, while patent protection can be a requirement for RBSOs operating in TM, it may also be important for firms developing and selling new products, as protection against imitation or for other strategic reasons (Arora and Ceccagnoli, 2006). In fact, patents can also be used as basis for negotiation, either with other patent owners (cross-licensing) or with owners of other types of resources (e.g. financial or technological). For the latter, patents prove the presence of “knowledge assets”, thus being a basis for valuing the company, or a way to signal technological competence in the establishment of technological partnerships (Coriat et al, 2003; Rothaermel, 2002). So, the

sole existence of patents may not necessarily differentiate between firms with different commercialisation strategies. However, firms operating in PM may have more possibilities to resort to alternative protection mechanisms - which can also be relevant, given the limitations of patents and small firms difficulties in enforcing patent rights on products being commercialised - and thus give relatively less importance to patents and/or attribute them different roles. Therefore, we also hypothesise that what may effectively distinguish firms on TM is the fact that, for them, the relevance of patent protection prevails upon that of other protection mechanisms, and also the potentially different roles they perceive patents to have.

Hip2c: RBSOs in TM are more likely to attribute higher importance to patents as protection mechanisms (as compared with other mechanisms), than RBSOs not in TM.

Hip 2d: RBSOs in TM are likely to attribute higher importance to patents as source of income (vs. other roles such as protection against imitation, source of reputation or means for cross-licensing), than RBSOs not in TM.

The impact of RBSOs origin on the appropriability conditions should also be taken in consideration. It can be argued that when knowledge being exploited was directly transferred from academic research, there is a greater possibility that it was patented. In fact, not only scientific knowledge may be easier to patent, but there is evidence that research organisations are put growing emphasis on the IP protection of the technologies with commercialisation potential (Wright et al, 2007). Such patents, are frequently transferred or licensed to the new firm, granting it IP protection from start-up. Given the information asymmetries in markets for technologies, the presence of patents filed by a reputed parent organisation can also have a function of quality endorsement of RBSOs (Lichtenthaler and Ernst, 2007). Thus the presence of parent patents can create favourable conditions for operating in TM. Therefore:

Hip2e: RBSOs in TM are more likely to start-up with technology protected by patents granted to the parent organisation, than RBSOs in PM

3.2.4 The impact of complementary assets on RBSOs strategic decisions

New firms engaging in the transformation of their technology into marketable products or services are confronted with the need to gain access (building or acquiring from others) to a number of non-technological assets (physical assets or knowledge and skills) that are necessary to sell a complete product or service: e.g., manufacturing capacity; marketing, sales and distribution; regulatory knowledge (Teece, 1986). Access to these assets can be done in different ways: through market acquisition, by building in-house, through an alliance with the owner of the asset (Colombo et al, 2006; Gans and Stern, 2003; Shan, 1990).

Those assets may be generic and supplied by the market in competitive conditions; or may be co-specialised to the innovation (Teece, 1986). The latter can be more difficult to access: they may not be readily available in the market, since their owners may try to achieve control over them, and they may also be difficult to imitate, because they are built on the basis of a process of learning within the firm (Rothaermel and Hill, 2005). The basic line of argument when discussing the commercialisation strategy of small technology-intensive firms is that when appropriability regimes are weak (and thus imitation relatively easy) the possibility to capture rents from the innovation depends on (privileged) access to complementary assets specialised to the innovation, that are required to produce and commercialise it (Teece, 1986).

New entrants will thus face a choice: they can build the key complementary assets internally; they can try to gain access to them, through market transactions or through alliances; or else they can avoid engaging in downstream activities at all (Arora et al, 2001). This choice can be addressed at two levels: a) that of the objectives pursued by the firm, i.e. its founders may or may not be willing to engage in a type of activity that requires downstream assets; b) that of the viability of gaining access to these assets in reasonably favourable conditions. These levels are not independent and it is their combined consideration that may contribute to explain RBSOs decisions.

It can be argued that the objectives pursued by RBSOs' entrepreneurs, are likely to be influenced by their origin and the nature of the technologies they are developing. In fact RBSOs may be exploiting knowledge that is still quite fundamental – e.g. concerned with basic principles or theoretical constructs – and thus still imprecise in terms of applications. Even if some applications are foreseen, extensive knowledge transformation may be required in order to accomplish them. It is not infrequent that RBSO founders have a body knowledge or a technology, but have not yet developed a specific application (product or service) and may even be uncertain about its final configuration (Stankiewicz, 1994).

The problem frequently confronted by RBSO entrepreneurs has its root in the basic distinction between technologies and products and in the difficulties associated with the transformation of knowledge into *working artefacts*, which are particularly serious for firms operating in fields of high technological opportunity, that enable the development of different products based in the same bodies of knowledge (Pavitt, 1998). This problem is both technological and managerial. In what concerns technological development, the competences of RBSO founders may be more adjusted to the processes that lead to the transformation of scientific knowledge into generic technologies (Autio, 1997), than with development of products, which will require building-up or gaining access to a much wider set of technical competences than those usually possessed by a science-based team (Marsili, 2002). Autio (1997) described a technological articulation process, through which scientific knowledge is transformed in basic technologies, which are still generic in nature, and then basic technologies are transformed into application specific technologies. Different types of firms are involved in these processes: science-based firms (which display characteristics present in academic spin-offs) are associated with the upstream transformation. This transformation may not be easily tackled by people who were not involved in the original development (Zucker et al, 1998) and can thus configure a business in itself, with which scientific entrepreneurs may find particular affinity.

The managerial problems are also pertinent: the commercialisation of technology intensive products requires specialised management competences and resources (Costa et al, 2004) and the presence or fast development of a diversified set of non-technological relationships (Mustar et al, 2006). Thus, the conduction of the whole transformation of a technology (which can be very basic) into a marketable product will require a diversity of investments in physical assets and competences that may be beyond the reach of a resource constrained start-up (Colombo et al, 2006)³.

Going back to Gans and Stern (2003) framework, the problem is compound if downstream assets that are key to the new firm, are specialised assets under the control of existing firms. In some circumstances new entrants may be able to enter in vertical alliances with the owners

³ The presence of external investors, namely venture capital, may change this scenery, improving firms' capacity to acquire / build at least some of the required assets (Heirman and Clarysse, 2007).

of the needed assets, as when established firms, to whom RBSOs technologies/products are particularly interesting, assume part or all the manufacturing and/or commercialisation activities (Rothaermel, 2002; Colombo et al, 2006; Stuart et al, 2007). These alliances can be mutually favourable, even if often characterised by a degree of power asymmetry (Shan et al, 1994). However, it may happen that key complementary assets are controlled by firms that have an interest in appropriating the technology (Gans and Stern, 2003). This particular situation may lead to opportunistic behaviour and, therefore, the perception of potential problems at this level can act as a constrainer upon the establishment of alliances, unless strong legal protection of the technology is guaranteed. In this latter case, however, firms can also choose to avoid engaging in the development of products/services and prefer to commercialise the technology instead, the literature showing that they may have some advantages in doing so, as we saw above. In fact, this type of behaviour will sometimes be present even in the context of alliances between small specialised firms and large incumbents, of which the case of biotechnology/ biopharmaceuticals is paradigmatic: the research-based specialised suppliers often supply contract research or sell patented technologies to the partner that possess the technological and commercial competences to transform it into a product and commercialise it (Stuart et al, 2007).

But it is not inevitable that RBSOs that exploit generic technologies and patent them – thus fulfilling basic requirements to engage in technology trade – follow this route. Gans and Stern (2003) framework also take in consideration the conditions that can lead technology-intensive start-ups to pursue with the development and sale of products, which are namely related with the conditions in which new entrants can themselves gain control upon the critical downstream assets. This can happen because these are not controlled by incumbents and can be obtained through arm-length contracts, or because the assets necessary to effectively commercialise the innovation are themselves new and can be co-developed with the technology, providing the new entrant with an additional advantage (Pisano, 2006; Jacobides et al, 2006).

Thus when fulfilling the conditions to compete in technology markets (regarding the nature of technology and the appropriability conditions, that act as a first constraint) RBSOs may effectively choose that route, or may still evaluate whether they have some advantages in building complementary assets and pursue with the development of products. The decision will be influenced by RBSOs perceptions of the importance of these assets for capturing the value from the technology and of the conditions in which these can be accessed – in particular their perception of the level control upon these assets by existing firms – as well as by the type of competences present in the firm.

The above discussion enables us to put forward a number of hypotheses on the impact of complementary assets upon RBSOs technology commercialisation decisions. It suggests that when key non-technological assets such as manufacturing capacity; marketing competences, sales and distribution facilities, regulatory experience, are perceived as controlled by existing firms, RBSOs will have a greater incentive to operate exclusively in the TM. Therefore:

***Hip 3a:** RBSOs are more likely to be in TM when downstream complementary assets perceived as key to capture the value from the technology are controlled by existing firms.*

The decision can also be influenced by the difficulty to build/acquire the assets, even if they are not controlled by incumbents. One basic element in this process are the competences present in the founding team, or those that can be mobilised through its networks (Elfring and

Hulsink, 2003). Firms find it easier to build or gain access to assets in areas in which they already have previous knowledge (Colombo and Piva, 2008). RBSOs, which originate from research environments, often lack non-technological skills and networks and thus need to undertake greater efforts in order to acquire downstream assets. While firms may subsequently recruit people with the additional competences, at early stages the knowledge base of the new firm is largely composed of the competences of the founding team. Thus, RBSOs whose founders have no previous industrial experience and/or have no management competences may prefer to operate in TM and thus avoid building the assets internally or engaging in the activities required to gain access to them externally, which tend to be facilitated by networks they do not possess and that will take them longer to develop.

Hip 3b: *RBSOs are more likely to be in TM when they do not possess the skills/networks to develop downstream complementary assets or access them in favourable conditions.*

Finally, the nature of the knowledge that is being exploited by RBSOs may require them to perform knowledge transformation activities that locate them upstream in the value chain. Such activities require good scientific competences and a strong emphasis on research activities. This upstream positioning makes it more complex for a small firm to encompass the whole range of competences that need to be brought-in in order to develop and commercialise a product, but, at the same time, creates better conditions for generating an output that can be patented and traded in technology markets. Thus these firms will have less advantage (and possibly less interest) in engaging on the development of downstream complementary assets, thus having a greater incentive to operate in technology markets.

Hip 3c: *RBSOs are more likely to be in TM when they are exploiting basic knowledge and thus are involved in upstream transformation processes which do not require them to engage in the development of downstream complementary assets*

4. Empirical analysis

In this section we test the hypotheses formulated above about the conditions that influence RBSOs commercialisation strategies, concentrating on the factors that are expected to influence the decision to target technology markets and the ability to operate in those markets.

4.1 Sample and data

The hypotheses are tested examining the strategies adopted by a group of 80 research based spin-offs firms (RBSOs) from six European countries (Belgium, France, Italy, Portugal, Slovenia, UK). The concept of spin-off adopted was the one defined in Mustar et al. (2006): new ventures created on the basis of formal or informal transfer of technology or knowledge generated by public research organisations.

The firms were selected from national databases on RBSOs, put together by the teams involved in the PICO project. The basic criteria used to build a first sample of firms, from which were selected the 80 cases, were age and growth orientation⁴. Considering the objectives of this research, it was decided to include only firms that were at least 5 years and no more than 15 years old, in order to guarantee that the RBSOs had achieved a reasonable level of development and defined a clear innovation strategy, but were not too distant from start-up, to limit the retrospective bias. Since it would not be possible identify firms denoting “growth-orientation” directly from a population, we defined the legal form as a proxy to it, assuming that growth companies are likely to wish to attract external financing and therefore also more likely to start up under (or adopt in the early years) a legal form – which varies between countries - that is flexible towards the capital/shareholder structure.

The final selection procedure also took into consideration the objectives of the research. Considering that commercialisation strategies can differ between sectors, the RBSOs were selected to show some heterogeneity in terms of industries. Heterogeneity was also sought in terms of type of activities performed, in order to encompass firms operating or willing to operate in product and in technology markets. In addition, there was also an attempt to include both firms with and without patents. As was pointed out above, recent work in commercialisation strategy focuses on companies that patented, while we were interested in looking at both groups and investigating also the role of patents in the strategic choice.

The empirical investigation is based on data collected for this purpose, as part of a questionnaire-based interview conducted in 2007. Data was obtained on firm’s activity (early, current and expected in future), IP protection, origin of technology and source of technological opportunities, technological relationships with parent, presence/control of downstream complementary assets, background and competences of founders and management team and financial resources. Generic information on firm operation (employees and sales) was also collected.

⁴ Given the objectives of this analysis, we were not interested in “life style companies”, that is, companies (usually consulting) created as side-business by founders whose main occupation remains in the academic sphere. Rather we were looking for firms that “started up with an ambition to grow”. But considering the age of firms and the nature of technologies being exploited, which may take some time to reach the market and start producing revenues, growth-orientation was judged to be more adequate than actual growth.

The final sample included firms in Biotechnology (25 firms), Software and Multimedia (23), Instruments (15), Electronics and Components (10) and a residual category of Others⁵ (7). About 25% of the firms were 10 years old or more, while about one half were between 5 and 7 years old. Regarding the activities performed, as measured by firms' main source of revenue at the time of the interview: 38.8% mentioned services, 30% products, 16.3% licenses and 15% did not have any revenue yet. Only about one half of the firms had already completed the development of the first product/ technology, so the firms' expectation regarding the main source of revenue *in the future* is also relevant to characterise them: 53.8% expected to have products, 27.5% licenses and 18.8% services. Thus 45% of the firms anticipated that the main source of revenue in the future would be different from the current one. Among these, 12 firms (33.3%) expected that change to involve having licenses as main source of revenue.

The majority of the firms mentioned that the technology was mostly developed at the parent organisation, being transferred (37.5%) or licensed (26.3%) to the new firm at start-up and only about 1/3 considered that it was mostly developed in-house. Several of the former had their technology protected by patents filed by the parent organisation (36.3%). Still regarding IP protection, about half of the firms had filed own patent applications. Combining the two sources, we conclude that 68.8% of the firms in the sample, had their technology protected by patents, either filed by the firm or by the parent organisation.

4.2 Description of the model

The data obtained from the questionnaire enabled us to build a number of variables that are used as multidimensional measures of the nature of the knowledge, appropriability and complementary assets, influence of parent organisation and founders' background.

4.2.1 Dependent variables

Our goal was to investigate the conditions that influence: a) RBSOs early decision to target the technology market (at the initial stage); b) RBSOs ability to operate in that market as the firm main business (at a steady state). Thus, we have defined two dependent variables, one for each stage.

For the first stage we used as dependent variable "main business orientation at start-up" (*TechMarket*). *TechMarket* is a categorical variable, which distinguishes between firms that chose "selling or licensing technology" as main business orientation at start-up and the firms that did not. This variable measures whether or not the firm decided to trade in the market for technologies at start-up. For each firm included in the sample, we collected data on its "business orientation at start up" and created a dummy variable *TechMarket*, valued 1 if the company chose to be in market for technologies, 0 otherwise.

For the second stage we used as dependent variable a measure of RBSOs capacity to earn money from the market for technologies: have licensing as main source of revenue in the future (*RevMainLic*). *RevMainLic* is a categorical variable, which distinguishes between firms whose main source of revenue expected in future are licenses and firms whose main source of revenue expected in future are not licenses, but products or services. The variable used is "expected source" instead of "present source" (which was also collected), to have a

⁵ Include: energy/sustainability, materials, cartographic systems, fine chemicals, sports equipment.

measure that is equivalent in all firms, in order to address the presence of firms in different stages of development and, namely, the cases in which firms still do not have any revenue, or in which services are the only source of income, while the technology is being developed⁶. Thus firms still at an earlier stage of development are answering about a more stabilised situation, towards which they are working. We are aware that expectations may not be achieved, but since our main objective is, in fact, to understand which type of conditions influence firms efforts to earn money in technology markets, we assume that such efforts can be explained by factors that are at work when firms are striving towards this objective - whether or not have already attained it. Thus, for each firm included in the sample, we collected data on the main source of revenue expected in future (products, services, licenses) and created a dummy variable *RevMainLic* valued 1 if the main source of revenue expected in future are licenses, 0 otherwise.

4.2.2 Independent variables

Appropriability measures.

We measure appropriability in several distinct ways. First of all we used patent data. Since very few firms had patents *granted* (13 firms, corresponding to 16.3% of the sample), we used patent applications as measure of presence of patents. Data on all patent applications (US and European patents and well as PCT) filed by the company was collected from patent databases and was subsequently cross-checked and completed with the firm. The patents were organised in families and the number of patent families was obtained for each firm. A dummy variable was built to measure the presence of any type of patent applications filed by the firm (*AppIFamY_N*) valued 1 if the RBSO had applied to at least one patent, 0 otherwise. In addition, in those cases where the technology originated from the parent organisation and was transferred to the new firms, we asked firms whether the technology was protected by a patent filed by the parent and built a variable *ParentPatent*, valued 1 if that was the case and 0 otherwise. On the basis of this data we also constructed a dummy variable *TechProtPat* valued 1 if technology is protected by any type of patents (own or parent), 0 otherwise.

We also collected qualitative data on IP protection. First we asked firms to rank, on a seven-point scale, the possibility and effectiveness of IP protection in the industry where they operate, defining a variable that measures the firms' perception of the level of appropriability in their industry (*IPIndustry*). Then we asked firms to rank, on a seven-point Likert scale, their perceptions of the importance of several appropriability mechanisms, both formal: patents, copyright or design protection, trademarks, confidentiality agreements; and informal: complexity of product design or of technology platform, lead-time advantage on competitors, moving quickly down the learning curve or rapid standardization.

On the basis of the answers to these questions we built two scale variables. The first measures the firms' perception of the importance of patents as IP protection mechanisms (*IPPatent*) and was directly based on the answer to the respective question. However, since we found that this variable was highly correlated with the variable measuring the firms' perception of level appropriability *in their industry (IPIndustry)*⁷ - suggesting that firms which attributed greater importance to patents as a protection mechanism also considered IP protection in their

⁶ 12 firms (15% of the sample) did not have any revenue at the time of the interview. Of the 31 firms (38.75% of the sample) that had services as main source of current revenue, 19 expected to have a different main source in future: 14 indicate products and 5 indicate licenses.

⁷ Correlation coefficient = -0,593 (P<0.01)

industry more possible and effective⁸ - we decided to use only the variable *IPIndustry* in our models. The second measures the firms' perception of the importance of other protection mechanisms, besides patents. As several non-patent protection mechanism variables showed a fair degree of internal consistency (alpha-Cronbach = 0,69) we decided to build a new variable (*AppNoPat*) by averaging over the values of those variables (secrecy, confidentiality agreements, lead-time, moving down the learning curve).

Data on parent patents was measured at start-up and the IP regime in industry can be regarded as a longstanding feature, thus being independent from the moment when the question was asked, so these variables are relevant to assess the conditions at early and current stage. Variables based on data on firm patents and perceptions of protection mechanisms can only be considered for the current stage, since they correspond to the activities conducted by the firm after start-up and thus cannot be regarded as potential determinants of early decision.

Nature of knowledge measures.

Qualitative data was collected to measure the level of novelty of the technology. For this purpose we used a measure developed by Eisenhardt and Schoonhoven (1990). Each firm ranked, on a seven- point Likert scale, the extent to which they considered that new technological knowledge had to be created to develop the technology (*TechInnov_DK*).

A variable was also created to measure the level of pervasiveness of the technology, combining the scope of the technology with the origin of technological opportunities, since pervasiveness was presented in the literature as deriving from the generic nature of scientific knowledge. Firms were asked to rank, on a seven-point Likert scale, the start-up technology in terms of scope, i.e. whether it was specific to an application (focused on a specific product/service) or was a platform technology serving as basis for several products, (*TechBroadStart*). They were equally asked to rank the importance of advances in academic research resulting from basic sciences, as sources of technological opportunities, on a seven-point Likert scale (*TechOppBasSci*). It was assumed that pervasiveness is higher when, simultaneously, the technology is broad and the importance of advances in academic research is high, which implies an interaction effect of those two variables⁹. To combine the effects, an interaction term *TechBroadStart*TechOppBasSci* was included in the models, which corresponds to the inclusion of a new variable, computed as the product mentioned. Using the product gives more weight to the cases where both of those variables receive a higher score, enhancing the firms concerned.

The founder's technological competences were measured on the basis of data collected on the background of each founder at the time of firm creation. For each firm we collected data on number of founders with university education in technological/scientific fields (*FoundEduTech*), the number of founders with technical experience in academic research (*FoundExpTechAc*) and the number of founders with a PhD degree (*FoundPhD*). The strength of academic background of the founding team was measured summing up the values of each of the variables described (*FoundExpAcad*). We also collected data on the number of founders with technical experience in industry and constructed a dummy variable

⁸ This is consistent with literature on small technology suppliers IPR that suggest that for this type of firms patents are the most (and often the only) effective IP protection mechanisms (Hall, 2005).

⁹ We tested the association between broadness of technology (*TechBroadStart*) and the dependent variables and found none, while both the scientific origin of technological opportunities (*TechOppBasSci*) and the combined measure showed association. This gave some support to our view that the simple fact that technology is *broad* is not sufficient to make be *pervasive*.

(*FoundExpTechIndY_N*) valued 1 if at least one founder had previous technological experience in industry, 0 otherwise.

All these variables are based on data measured at the time of start-up, so they can be used in the analysis of early and current conditions.

Complementary assets measures.

Previous studies have used different proxies of complementary assets (CAs)¹⁰ but only Gans et al. (2002), have asked directly the firms about their perceptions of the incumbent level of control upon key CAs. While entrepreneurs may not have complete understanding of the competitive environment and while their perceptions may not reflect the actual situation in what refers to the ownerships/control of downstream assets that are key to capture the value of their technology, it is their perceptions that influence decision making. Therefore we attempted to capture this dimension.

To measure firms perception of level of incumbent control upon the different assets, we asked each firm to consider the resources and competences judged to be key to earn profits from the innovation in three domains - manufacturing; marketing and advertising; sales and distribution¹¹ - and to rank, on a seven-point Likert scale, the relative position of the RBSO and of other firms, regarding the control upon them. The scale was designed to consider a set of possibilities that ranged:

- from the complete control by the RBSO, that corresponds to its ownership of the assets (extreme left of scale)
- through situations where there is relative control of the RBSO – the balance of power is on the side of the RBSO, who can establish favourable or mutually favourable agreements with other companies to guarantee access (example: this is likely to happen with other small firms to whom the agreement is equally important for their business development)
- through the situation when the assets are freely available in the market at competitive prices (mid-point of scale)
- through situations where there is relative control by established firms – the balance of power is on the side of the established firm (usually large), who still establishes agreements with the RBSO, but given its financial capacity / market power have a dominant position and can make the rules.
- to complete control by established firms that own the assets themselves and can (and possibly do) effectively constrain access (extreme right of scale).

A reliability analysis upon the variables obtained from the questionnaire (level of control upon manufacturing, upon marketing and upon sales: respectively *CACTRLMft*, *CACTRLMkt*, *CACTRLSales*) revealed a poor Cronbach alpha (0,54), that increased substantially when omitting the first one (0,72), suggesting the existence of two underlying dimensions, which was corroborated by a 2-dimensional PCA (principal components analysis) upon them. Consequently, a final measure was obtained on the basis of two variables: a) level of incumbent control upon manufacturing (*CACTRLMft*), directly obtained

¹⁰ Examples of measures used: firm market share in a segment (Fosfuri, 2006); degree of interaction between R&D and production personal (Arora and Cecagnoli, 2006); presence of production, marketing, sales facilities (Novelli and Rao, 2007). Gambardella and Giarratana (2007) use proxies specific for the software sector, based on firm trademarks).

¹¹ Firms were also asked about regulatory assets, but this type of assets was found to be very specific to firms in certain industries and thus was not include in the analysis.

from the questionnaire; b) level incumbent control upon commercialisation assets (*CACTRLComm*), which corresponds to the mean of the variables relative to level of control upon marketing and to level of control upon sales.

To complement the data on perceptions on CA control, we have also assessed whether the firm effectively owned one particular asset: manufacturing. We used employment as proxy to ownership of the asset and created a variable (*FTEProduction*) that computes the number of full time equivalent employees in the production function at the time of the interview¹².

While the entrepreneurs perceptions on CAs at start-up might also have been relevant for the early decisions, it was considered that the data on perceptions collected at least 5 years after start-up would reflect the respondents current understanding of the situation. Moreover, this understanding could result, at least partly, from past strategic decisions in terms of firms positioning. Therefore, these variables would not have explanatory power regarding early decisions. In order to attempt some approximation to the start-up situation, we used non-technological competences in the founder team as a proxy to firms' potential to build, acquire or gain access (through networks) to downstream assets. Since academic entrepreneurs are described as having limited knowledge of the industry/market where they are entering, as well as limited competences and links in non-technological fields, this measure reflects the assumption that such knowledge, competences or networks are likely to increase with the presence of founders with previous industrial background. Thus, we used data on the background of entrepreneurs at the time of start-up to build a variable (*FoundPrevMgmtExp*) that computes the number founding entrepreneurs with previous non-technological experience in industry.

4.2.3 Control variables

Considering that some industries are likely to be more favourable to the operation of markets for technologies, we collected data on current activities of each firms and its industrial classification and constructed five dummy variables according to the industrial segment in which the firm operates: *Soft_Mult* (=1 if industrial segment are software and multimedia); *Inst* (=1 if industrial segment are instruments); *Elect_comp* (=1 if industrial segment are electronics and components) and *Biotec* (=1 if industrial segment are biotechnology).

Finally we considered *Age* as the number of years of the firm at the time of the interviews (2007). Since operation in technology markets is described as a relative recent phenomenon it is possible that this business orientation was more frequently chosen by younger firms.

In Appendix are summarised the variables used in the analysis, and presented some descriptive statistics for each of them

¹² Novelli and Rao (2007) use the presence of in-house facilities (manufacturing, marketing and sales) as the indicator of control over CAs. However, by adopting only this measure, these authors exclude the possibility that firms can access and still achieve some control upon these assets, through favourable contractual agreements. This possibility was considered in our question about control.

4.3 Empirical results

To test our hypotheses we used a two step approach. First, we focused on the conditions that influence RBSOs early business orientation towards a technology market and defined one model (Model 1), whose dependent variable is the main business orientation at start-up (*TechMarket*) and whose independent variables are measures of:

- appropriability: perception of appropriability regime in industry (*IPIndustry*) and presence of a parent patent protecting the technology (*ParentPatent*);
- nature of knowledge: both direct measures such as novelty and pervasiveness of technology (*TechInnov_DK*, *TechBroadStart* TechOppBasSc*), and indirect such as strength of founders academic backgrounds (*FoundExpAcad*) and presence of founders with technical experience in industry (*FoundExpTechIndY_N*).
- ability to build complementary assets: proxied by the strength of non-technological competences in founding team (*FoundPrevMgmtExp*).

Second we addressed the conditions associated with earning money from the market for technologies as the RBSO main business. We defined two models (Model 2 and Model 3), whose dependent variable is “licensing as main source of revenue in the future” (*RevMainLic*), and that included the early decision (Model 2) or its determinants (Model 3) as independent variables. For this purpose, in Model 2 we used as *independent variable* the early decision to operate in technology markets (*TechMarket*) and excluded from the model the variables identified in Model 1 as explanatory of that decision. Conversely, in Model 3 we tested whether factors that were determinant for the early decision remained important in later stages and thus included the variables identified in Model 1 as explanatory of that early decision, as *independent variables*.

In both models, we also included as independent variables, the measures of appropriability (*IPIndustry*) and nature of knowledge (*FoundExpAcad*) that were not found to have explanatory power for the early decision, and have also introduced new measures of appropriability and control over complementary assets that took in consideration the fact that the RBSO was already in operation.

In the case of appropriability, we included the perception of appropriability regime in industry (*IPIndustry*) in both models, but the measures used for presence of patents differed. In Model 2 we used *TechProtPat*, which combines own and parent patents, thus measuring whether the technology is protected by patents, regardless of their origin. In Model 3, parent patents were included independently as one of the determinants of early decision, and thus we included a measure of own patents (*ApplFamY_N*).

In the case of nature of knowledge, Model 2 only included one (indirect) measure – strength of founders academic backgrounds (*FoundExpAcad*) – since all other variables were found in Model 1 to be determinants of early decision (thus being excluded from Model 2, according to the rationale described above). Conversely Model 3 included the whole set of variables measuring nature of knowledge, both direct measures such as novelty and pervasiveness of technology (*TechInnov_DK_inv*, *TechBroadStart* TechOppBasSc*), and indirect measures such as presence of founders with technical experience in industry (*FoundExpTechIndY_N*) and, once again, strength of founders academic backgrounds (*FoundExpAcad*).

In the case of complementary assets, both Model 2 and Model 3 included the perceptions of control upon assets related with production and commercialisation (*CACTRLMft* and

CACTRLComm) and employment in production activities as a measure of presence of the manufacturing assets (*FTEProduction*). In addition, in Model 3 we also included the measure of founders' previous non-technological experience (*FoundPrevMgmtExp*), which was found to be determinant in Model 1 (thus being excluded from Model 2).

We run the models, using logistic regression due to the dichotomous nature of the dependent variables¹³.

4.3.1 Factors that determine early decision (Model 1)

In the case of Model 1, estimated odd ratios, reported in table 2, provide strong support for the hypothesis that the novelty of technology (*TechInnov_DK*) increases the odds of opting for operating in the technology market. However, we did not find support for the hypothesis regarding the impact of pervasiveness of the technology – at least measured as a combination of technology scope and importance of basic science. In fact in this case the estimated odd-ratio is below 1, which means a slight reduction on the odds of opting for operating in the technology market. Regarding the impact of founders' backgrounds on the nature of knowledge, our results show an inverse¹⁴ and significant relationship between the founding team's previous technical experience in industry (*FounExpTechInd*) and the decision of operate in the technology market. However, the strength of academic backgrounds of founding team (*FoundExpAcad*) was not found to have any impact upon that decision. Thus, Hypothesis 1D was only partially supported.

Table 2 – Model 1: Results of logistic regression

Variables	Exp (B)	
	Model 1 Step 1	Model 1 Final Step
IPIndustry	0.946	
ParentPatent	6.636**	5.629**
TechBroadStart*TechOppBasSci	0.941**	0.942**
TechInnov_DK	2.131**	2.101**
FoundExpAcad	1.016	
FoundExpTechIndY_N	0.123**	0.111**
FoundPrevMgmtExp	3.498**	2.892**
Soft_Mult	1.957	
Elect_comp	1.085	
Instr	0.360	
Biotec	5.834	6.641**
Constant	0.013**	0.17**
R²N	0.526	0,504
Valid N	73	73

* Sig <= 0.10

** Sig <= 0.05

The results also show that the fact that technology was protected by patents filed by the parent increased the odds of opting for operating in the technology market. This result provides some support to the hypothesis that RBSOs starting-up with technologies developed in the context of the parent research organisation are more likely to opt for operating in the TM. It also provides some support to the hypothesis that protection by patents is important

¹³ The method used was backward stepwise LR

¹⁴ As the proportionate change of odds (Exp b) is below 1.

for the decision to operate in TM, even if at this early stage that protection is provided by a parent patent.

Regarding the proxy to the ability to build complementary assets, we found that, contrary to the expected, previous managerial experience in industry (*FoundPrevMgmtExp*) increases the odds of opting for operating in the technology market.

We also find an industry effect in our analysis: the results show that the odds of operating in the technology market increase significantly when the industry is biotechnology (*Biotec*), confirming that biotechnology firms are more likely to opt for operating in the technology market than those in other industries.

4.3.2 Factors that influence having TM as main business (Model 2 & Model 3)

Impact of the early decision upon future activity

Results from Model 2 suggest a significant impact of an early business orientation towards technology markets on the odds of having licenses as main source of revenues in the future (Table 2). This decision emerges as the strongest influence upon the ability to operate in technology markets, as the firm main business. However, Model 3 - that tests whether the variables that were found to be determinants of early business orientation towards technology markets still influence the firms' subsequent orientation - shows that only some of these variables remain significant (Table 4): presence of a parent patent (*ParentPatent*) and being in biotechnology industry (*Biotec*). Rather, variables related with the nature of the knowledge (novelty or pervasiveness) or with founders' background are not significant anymore.

Other factors associated with expectation of having licenses as main source of revenue

Model 2 and Model 3 also tested the impact of other factors, besides early decision or its determinants, that were expected to be associated with the subsequent behaviour of the firm.

Table 3 – Model 2: Results of logistic regression

Variables	Exp (B)	
	Model 2 Step 1	Model 2 Final Step
IPIndustry	0.529*	0.515**
FoundExpAcad	0.636**	0.658**
CACTRLComm_nm	2.026**	2.001**
CACtrlMnf_nm	1.468	1.557*
FTEProduction	0.400*	0.399*
TechProtPat	2.332	
AppNoPat	2.232**	2.288**
Age	0.531**	0.527**
TechMarket	94.333	84.958***
Constant	0.549	0.759
R ² N	0.719	0.714
Valid N	77	77

* Sig <= 0.10

** Sig <= 0.05

*** Sig <= 0.01

Table – Model 3: Results of logistic regression

Variables	Exp (B)	
	Model 3 Step 1	Model 3 Final Step
ParentPatent	13.566*	13.714***
TechBroadStart*TechOppBasSci	0.953	
TechInnov_DK_inv	1.626	
FoundExpTechIndY_N	0.135	
FoundPrevMgmtExp	1.954	
Biotec	105.651***	30,049***
IPIndustry	0.652	
FoundExpAcad	0.644*	0.798
CACtrlComm_nm	1.078	
CACtrlMnf_nm	1.677	
FTEProduction	0.473*	0.523**
ApplFamY_N	0.071	
AppNoPat	1.331	
Age	0.739	
Constant	2.134	0.253
R²N	0.774	0.668
Valid N	70	70

* Sig <= 0.10

** Sig <= 0.05

*** Sig <= 0.01

In Model 2, we find that perceptions of high appropriability regime in industry (*IPIndustry*) increase the odds of having licenses as main source of revenues in the future, providing support for Hypothesis 2A. However, presence of patents (*ApplFamY_N*), per se, has no significant impact, confirming our suggestion that they may also be relevant for firms that operate in PM. The high correlation between *IPIndustry* and *IPPatent*, already mentioned above, suggests that firms that perceive a high level of appropriability in their industry also rate highly patents as protection mechanisms, thus providing also some support to Hypothesis 2C. But, contrary to our expectations, we find that perceptions of a high importance of non patent mechanisms (*AppNoPat*) also have a positive influence on licensing as future source of revenues. Thus, there is only partial support for the hypotheses on appropriability: perceptions of level of IP protection in industry are important, but presence of patents does not differentiate firms that expect to be in the TM as main business. In addition, these firms appear to rate more highly both patents and non-patent mechanisms as means of IP protection. Thus, the latter, instead of being less important to firms operating in TM, are possibly regarded as an additional means of reinforcing their capacity to protect their intellectual assets.

In the case of Model 3, neither perceptions of appropriability regime in industry, nor perceptions of importance of non-patent protection mechanisms, nor presence of patents filed by the firm, were found to be significant. However, in this model the presence of parent patents was tested separately and was found again to have a strong impact upon the odds of having licenses as main source of revenue in the future. Given the formulation of the model, it was possible that the strong impact of the variable *ParentPatent* somewhat “shadowed” the impact of the variable *IPIndustry*, that measures the perceptions of appropriability in industry. Thus we tested for the association between these two variables. It was found that, effectively, there is a strong association between them, suggesting that there is a tendency for

firms whose technology is protected by a patent filed by the parent to perceive appropriability in their industry to be higher¹⁵.

Regarding the nature of knowledge, both models tested the strength of academic backgrounds of founding team (*FoundExpAcad*). It was significant in Model 2, but contrary to expected, it was found to decrease the odds of having licenses as the main future revenue. The other variables measuring the nature of knowledge, both directly (novelty and pervasiveness) and indirectly (impact of founders technical backgrounds in industry) were only included in Model 3, but they were not found to be significant.

The new measures of control over complementary assets were tested in Model 2 and Model 3. In Model 2 we found that a higher level of incumbent control upon manufacturing assets and upon commercial assets (*CACTRLMft* and *CACTRLComm*) increased the odds of having licenses as main source of revenues, providing support for Hypothesis 3A. These variables were not found to be significant in Model 3. Also in Model 3, the variable introduced in Model 1 as proxy to the ability to build/access CAs (*FoundPrevMgmtExp*) was not found to be significant anymore.

However, in both Models 2 and 3 we found a significant and inverse relationship between the number of employees in production activities (*FTEProduction*), as an indicator of presence of manufacturing CAs, and the licenses as main source of revenues. This confirms that firms with higher investment effort in production are less likely to operate in technology markets, thus providing support for Hypothesis 3B. This is not unexpected, since it is possibly the result of a decision: firms in PM are more likely to have already built some production capacity!

Finally the results of Model 2 show a negative impact of *Age* on the odds of having licenses as main source of revenues. This result leads to the conclusion that propensity to expect to operate in the technology market as the main business is higher among firms that were created more recently, supporting the idea that having TM as main business is a relatively recent phenomenon¹⁶. In addition, Model 3 shows again strong influence of being in biotechnology industry on the odds of having licenses as main source of future revenue.

For structural reasons, it was not possible to include in the models the test of Hypothesis 3D on appropriability, concerning the role attributed to patents. In fact, since the respective questions were only answered by firms that patented, their inclusion would reduce the number of cases in the analysis and, particularly, would lead to the exclusion of all the non-patenting firms. Despite the limited number of cases we have nevertheless tested separately for the association between the variables measuring the importance attributed by RBSOs to

¹⁵ Ergo, with lower marks on *IPIndustry*; t-test, sig < 0.01, with sample means 4.1 and 2.3, for firms not protected and protected by parent patents, respectively.

¹⁶ It would also be possible to argue that operating in the TM is an early stage strategy and thus it is more likely to be adopted by *younger* firms (although it may be a temporary strategy). The nature of our dependent variable – that concerns expectations in terms of firms' main *business in the future* and not firms' *current business* - suggests our interpretation. But it may be possible that the age effect has some impact upon the expectations of the younger firms, which may still evolve according to the evolution of their conditions (e.g. technology development completed, granting of patents, attempts to licensing, etc). We tested for the association between the age of the firm and early business orientation and while we found that firms that mentioned an early orientation towards TM were more frequently younger, the relationships was not statistically significant.

different roles of patents¹⁷ and the expectation of having licenses as main source of revenue. The results show a significant relationship between the value attributed to patents as source of income and the type of market, with firms operating in technology markets valuing more that role¹⁸. Likewise, firms not operating in technology markets were found to value significantly higher patents as a means to enhance reputation¹⁹. Both relationships partly confirm our hypothesis that patents play different role for firms adopting different strategies.

4.4 Discussion

The results obtained confirm that early choices have a strong impact on subsequent business orientation: an early decision to target technology markets increases the propensity to operate in this market in the future. However, they also suggest that the conditions that influence the early adoption of a commercialisation strategy are not necessarily the same that influence the subsequent ability to sustain that strategy, although some of them appear to remain relevant.

Regarding the conditions associated with adopting and with sustaining a technology market commercialisation strategy, the empirical research have confirmed some of our hypotheses, but have also produced a few puzzling results. As expected, it was concluded that this strategy is more likely to be adopted when: the technology being exploited involves a greater component of new knowledge; the technology was already developed in the parent organisation and was protected by a parent patent; the firms are created by founders without previous technological experience in industry; the RBSO is in the biotechnology industry (these being also more likely to be the ones to operate in this market as their main business in the future). Some of these results also support the importance of the parent technological influence, or more generally, the relevance of RBSO features that are associated with their origin. In particular, the impact of the presence of patents filed by the parent can be regarded as an indirect indicator of relevance of the technology developed in the academic context. It may also potentiate the intervention of the parent (as patent owner) on the decision about the commercialisation mode

Another expected result was the finding that this commercialisation strategy was more likely to be sustained when RBSOs operated in sectors where appropriability was (perceived by the entrepreneurs) as higher and when some key downstream assets, related to production and commercialisation, were perceived as controlled by existing firms. Similarly firms operating in technology markets would be less likely to build manufacturing capabilities. While the latter result is almost self-evident - since firms who build manufacturing assets are expecting to engage in production – the results regarding control upon assets are important, since they confirm recent research that places control upon complementary assets as a key element on strategic decisions. In our case, we opted for assessing the impact of perceptions on the strategic decision, exactly because the *presence* of the assets can already be the result of a decision. Our results confirmed that RBSOs who wish to operate in technology markets are also more likely to be those that perceive a stronger control of incumbents upon assets that are necessary to develop and sell a product or service.

¹⁷ Firms that patented were asked about the importance they attributed to the following motives: get licensing revenues and secure income; prevent imitation; enhance reputation; basis for negotiation (cross licensing); protection against suits.

¹⁸ t-test, sig < 0.01, with sample means 6.3 (TM) 3.5 (others).

¹⁹ t-test, sig < 0.01, with sample means 3.3 (TM) and 4.8 (others).

Among the puzzling results is the fact that, contrary to what has been proposed in the literature (e.g. Gans et al, 2002), the presence of patents (except parent ones) does not differentiate between RBSOs operating in technology or in product markets²⁰. However, this departure from other studies was not completely unexpected and may derive from the fact that the vast majority of them has focused exclusively on firms with patents, which was not the case here. Our result can be related to the fact that knowledge intensive firms operating in product markets may also require good IP protection. Indeed, according to what was expected, the difference between these firms and firms operating in technology markets is that the latter appeared to rate more highly patents as IP protection mechanisms and also to assign them different roles. What was relatively unexpected was the fact that non-patent IP protection mechanisms were more important for firms operating in technology markets, contrary to what we had hypothesised. A possible explanation is that, since IP protection is particularly critical for these firms and since patent protection is not always completely effective, they need to rely on a combination of mechanisms, which globally provide a more efficient protection (Hurmelina-Laukkanen and Puumalainen, 2007). This is an interesting result that adds to our understanding of the behaviour of firms in TM.

However, the above conclusion regarding the non relevance of patent ownership for RBSOs strategic decision may need to be re-evaluated, if we consider two aspects. The first one is the continued impact of the patents filed by the parent organisation. This impact may partly reflect the “political” influence of the parent in the decision on the commercialisation mode. But it also reflects the importance of the IP protection offered by the patent that the RBSO inherits from the parent, which presumably defends the technology which drove the spin-off process²¹. If we add the fact that several companies were still developing their technologies and the fact that most of the firms that had filed own patent applications did not have any granted patents, we start devising a scenery that may be quite RBSO-specific: own patents may not have yet emerged in firms that are exploiting knowledge that is more science-based and thus further from application, thus requiring a more substantial transformation. Rather, at this stage, their technologies are protected by the patents that were filed by the parent. This situation may partly explain why own patents were not found to have a higher impact on these firms’ decision and also why they rate so highly the importance of other protection mechanisms. If that is the case we cannot yet definitively conclude that patents are as relevant for RBSOs that target technology markets as they are for the ones that do not.

A puzzling result was also obtained for the pervasiveness of the technology (that is, the capacity to generate a continuous stream of opportunities), which was found to decrease slightly the odds of operating in a technology market. These results may be related to the very nature of pervasive technologies, which enable a wide variety of applications, thus giving firms a large margin of strategic choice. Thus, we can speculate that knowledge intensive firms operating in product markets, namely those operating in fast changing markets, may have some advantages in exploiting pervasive technologies that enable them to develop a sequence of innovative products (Kim and Kogut, 1996). Also, contrary to our expectation,

²⁰ Notice however that most authors use patents *granted*, which correspond to a definitive guarantee of property rights, while we used patent *applications* (since the vast majority of firms with patent applications had not yet been granted the patent). This could introduce some differentiation in terms of bargaining capacity, which might explain longer periods until firms get revenue from licenses (Gans et al, 2007), but while this may impact upon current revenue, it is less likely to impact upon expected revenue. Indeed no association was found between presence of patents granted and the main expected source of revenue. On the other hand, some authors use the presence and the number or strength of patents (Shane, 2001), which was not considered here.

²¹ In the case of 14 firms the technology was still *only* protected by patent parents, which corresponds to 25.5% of the firms who had technology protected by any type of patent

this strategic orientation was not favoured by the strength of academic backgrounds among founders and was more likely to prevail when founders with non-technological backgrounds were present in the team.

The results obtained for these two variables, suggest that we rethink the measures used for the factors they were expected to operationalise. In fact, a possible explanation for the positive impact of non-technological backgrounds on the propensity to operate in technology markets, may be the intervention of external shareholders, who are often brought in at early stages in this type of firm and who tend to advocate the presence of these competences in the team (Hellman and Puri, 2002). This means that this variable is indeed a good measure, but not necessarily of what we used it for and thus, that we need to find a better measure for the control over complementary assets at early stages. In the case of strength of founders' academic backgrounds, we may need to abandon the cumulative approach, since it may not result as expected, but rather lead firms with bigger teams to appear as strong, or stronger, than those with smaller teams, even if their members do not have the combination of higher degrees and R&D experience we wished to capture.

The results obtained are still exploratory and based on a relatively small sample. One possible limitation of this analysis is that, from the statistical point of view, when using logistic regression, small samples may lead to unstable results, in the sense that the omission of a single observation could originate a quite different adjusted model. Because our objective is to take into consideration a combination of factors (measured in a multidimensional way), which we expect can provide a more comprehensive explanation of the phenomenon, it may be necessary to expand our sample, in order to increase the robustness of the results. In order to overcome some of the limitations of this analysis, on the basis of the data available, we can still expand our work in several directions. We can develop some more sophisticated models, of both dependency and interdependency type. The former might include a more elaborated 2-step approach, if an appropriate instrumental variable is found. Or, if we find some characteristics that change in time (e.g. that can be analysed along two or even three stages considered in our framework: start-up stage; current stage; expected situation at a "steady state") we might try to follow a panel data approach.

5. Conclusions and Policy Implications

This paper addressed the commercialisation decisions of research-based spin-off firms, focusing on the case of companies that choose to target the market for technologies. Combining insights from two streams of literature - economics of technological change and strategic management of technology - we discussed the conditions that can influence firms' ability to pursue with this strategic orientation; and advanced some theory-driven hypothesis regarding the key factors that are likely to determine their choice: nature of knowledge, appropriability conditions, location and degree of control upon complementary assets and institutional setting of origin. Our analytical framework takes in consideration a combination of factors that tend to be addressed separately and the respective impacts; and also brings back into focus some aspects – namely those related with the nature of the knowledge being exploited – that are often overlooked.

The results of a first empirical test of these hypotheses on a sample of 80 European RBSOs provide some insights into the conditions that are associated with RBSOs decision to adopt a technology market commercialisation strategy, and with the capacity to maintain this strategic orientation beyond the early stages assuming the operation in technology markets as

the firm main business. Globally they appear to provide a more effective explanation of the conditions that lead RBSOs to adopt an early business orientation towards technology markets (as compared with those that do not adopt that orientation) than of the conditions that influence RBSOs capacity to operate on technology markets as their main business (as compared with the ones that do not). In fact, even if early conditions appear to have some imprinting effect upon firm subsequent behaviour, the set of factors that influence that behaviour, contributing to steer RBSOs subsequent orientation, are likely to increase in number and complexity as firms evolve (Vohora et al, 2004). However, our results confirm that combining factors related with the nature of knowledge, appropriability and access to complementary assets it is possible to gain a better understanding of the RBSOs commercialisation strategies.

This research contributes both conceptually and empirically for an explanation of the factors that are behind the emergence and sustainability of a model of entrepreneurial behaviour, which is becoming increasingly frequent in science based fields - the company that opts for specialising in the production and sale of intellectual property, as opposed to pursuing with the development and market introduction of products or services based on it. It adds to the still incipient research on this model of behaviour and also to recent research on the determinants of the commercialisation strategy of small technology-intensive firms (Giuri and Luzzi, 2005; Hicks and Hedge, 2005; Novelli and Rao, 2007; Gans et al, 2002; Gambardella and Giarratana, 2007; Pries and Guild, 2007).

The research also led us to conclude that those factors encompass several features that are often associated with RBSOs (e.g. regarding characteristics of two of its main assets: the technology and the entrepreneur), suggesting a potentially higher propensity of RBSOs to operate under this model. Thus, by exploring this emerging strategic path and the behaviour of RBSOs that pursue it, this research has provided some conceptual and empirical insights into one of the less understood routes through which RBSOs perform their knowledge production and transformation function. It is our contention that firms adopting this model have specific functions in the innovation system, that are expressed on the nature of the transformation tasks they perform, on the outcomes of these tasks and on the knowledge articulation role they play throughout their interactions with knowledge partners, suppliers and clients (both private and public). It is therefore important, from a policy standpoint, to consider more attentively the RBSOs that adopt this type of business orientation. Against this background, the results of this research, although still preliminary, are politically relevant, since they call the attention to this specific model of RBSO behaviour and provide information on the conditions that favour its adoption and that make it viable.

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Appendix

Table A1 – Summary statistics for the dependent and independent variables

Variables	Definitions	Valid N	Mean	Standard Deviation
Strategic orientation measures				
TechMarket	Dummy=1 if company operates on market for technologies at start-up	80	0.30	0.461
RevMainLic	Dummy=1 if the main source of revenue expected in future are licenses	80	0.28	0.449
Appropriability measures				
ParentPatent	Dummy=1 if company has parent patent at start-up	76	0.38	0.489
IPIndustry	7-point Likert scale rating of perception of appropriability regime in industry	79	3.38	2.021
IPPatent	7-point Likert scale rating of importance of patents as protection mechanisms	80	5.05	2.449
AppNoPat	7-point Likert scale rating of importance of non-patent protection mechanisms	80	4.88	1.457
TechProtPat	Dummy=1 if technology is protected by patents (own and/or parent)	80	0.69	0.466
AppIFamY_N	Dummy=1 if company has patents (applications)	78	0.56	0.499
Nature of knowledge measures				
TechBroadStart	7-point Likert scale rating of broadness of technology	78	4.53	2.306
TechOppBasSci	7-point Likert scale rating of importance of basic science as source of technological opportunity	79	3.41	2.367
TechBroadStart*TechOppBasSci	Pervasiveness (combines 7-point Likert scale rating of broadness & of importance of basic science)	77	15.74	14.95
TechInnov_DK	7-point Likert scale rating of novelty: extent of creation of new knowledge	80	3.93	1.756
FoundExpAcad	Strength of academic backgrounds of founding team	79	7.28	3.84
FoundExpTechIndY_N	Dummy=1 if founders had previous technological experience in industry	80	0.63	0.485
Complementary assets measures				
FoundPrevMgmtExp	Number of founding entrepreneurs with non-technological experience in industry	79	0.63	0.819
CACTRLMft	7-point Likert scale rating of perceptions on <i>level of control</i> upon manufacturing	80	3.00	1.911
CACTRLComm	7-point Likert scale rating of perceptions on <i>level of control</i> on marketing & sales	80	2.86	1.756
FTEProduction	Number of employees in production activities in full-time-equivalents	78	2.27	8.554
Firm-level controls				
Soft_Mult	Dummy=1 if industry is Software and Multimedia	80	0.29	0.455
Inst	Dummy=1 if industry is Instruments	80	0.19	0.393
Elect_comp	Dummy=1 if industry is Electronics and components	80	0.13	0.333
Biotec	Dummy=1 if industry is Biotechnology	80	0.31	0.466
Age	Age at time of interview	80	8.23	2.093

Table A2: Association between dependent and independent variables
(Mann-Whitney Tests except * Fishers' exact test)

	Significant differences at 0.1			
	TechMarket	Sig	RevMainLic	Sig
Appropriability				
IPIndustry	+	.004	+	.000
*ParentPatent			+	.000
IPPatent			+	.000
AppNoPat			N	
*AppIFamY_N			N	
*TechProtPat			+	.008
Nature knowledge				
TechBroadStart	N		N	
TechOppBasSci	+	.022	+	.016
TechBroadStart*TechOppBasSci	+	.014	N	
TechInnov_DK	+	.012	N	
FoundExpAcad	N		N	
*FoundExpTechIndY_N	N		N	
Complementary assets				
CACTRLMft			+	.000
CACTRLComm			+	.071
FTEProduction			-	.004
FoundPrevMgmtExp	+	.039	+	.013
Firm-level controls				
*Soft_Mult	-	.057	-	.002
*Inst	N		-	.056
*Elect_comp	N		N	
*Biotec	+	.001	+	.000
Age			-	.016
TechMarket			+	.000