RESEARCH-BASED SPIN-OFFS TARGETING THE MARKET FOR TECHNOLOGIES: A CONCEPTUAL MODEL

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Research-based spin-offs targeting the market for technologies: a conceptual model[1]

ABSTRACT:

This paper addresses the commercialisation decisions of research-based spin-off firms, focusing on the case of companies specialising in the production and sale of intellectual property - a model of entrepreneurial behaviour increasingly frequent in science-based fields, and that research-based spin-offs may be more prone to adopt given their specific characteristics. Combining insights from the economics of technological change and the strategic management of technology literature, we discuss the conditions that influence spin-offs ability to pursue with this strategy, and advance some theory-driven hypothesis regarding 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 - and their impact upon firms' decisions. We add to the still incipient research on this model of behaviour, as well as to recent research on the determinants of the commercialisation strategy of small technology-intensive firms.

Key Words: Research-based spin-offs; Knowledge transformation; Commercialisation strategies; Entrepreneurial decisions; Market for technologies

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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 in economic.

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 or technologies 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 through which it will capture value from their knowledge assets. It may opt for engaging in the development of products or services based on that 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 decision 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 the 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 now becoming more frequent, particularly in science-based 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 an 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 -

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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 testable hypothesis regarding their impact upon RBSO strategic decisions.

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)[1]. 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 the 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 (IPR) 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

[1] Firms that engage in product development may also chose to simultaneously sell/license (part of) their technologies, for various reasons (Lichtenthaler, 2008). But this option is less likely in start-ups, which tend to be too resource constrained to diversify their strategic options. They may nevertheless engage in some technology trade activities, while developing the core product (Kollmer and Dowling, 2004), particularly intellectual property sales in the form of R&D services.

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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 was 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 firms applying this strategy 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 technology 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 characteristics. 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 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, Di Gregorio and. Shane, 2003).

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 and their strategic choices.

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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 an Orsenigo, 1993); b) related with conditions that enable firms to capture value from their technology (Teece, 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 (usually described in the literature as "complementary assets"), 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 the decision process, namely through their impact upon the above mentioned dimensions.

In line with this framework, we advance that RBSOs decision regarding commercialisation strategy will be influenced by four types of factors: nature of knowledge being exploited; appropriability conditions, i.e. capacity to protect the technology; location and control of key complementary assets; characteristics of the firms' source environment (particularly relevant at start-up), expressed through the direct or indirect influence of the parent organisation and through the impact of founders background upon the firm early competence base.

In the next sections we present in detail the theoretical foundations of this framework and formulate several 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.

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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.

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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 "menus" 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 cumulativeness 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 cumulativeness, 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 cumulativeness is low, but in conditions of high pervasiveness, cumulativeness 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).

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Thus, globally, conditions of high technological opportunity, particularly when associated with pervasiveness, high appropriability and low cumulativeness appear to be the most favourable for 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. If we consider exclusively the entry conditions in terms of the nature technology, it is to be expected that firms willing to operate in markets for technology will have more stringent requirements concerning the level of opportunity, pervasiveness and also of appropriability, given the greater vulnerability of small firms at the latter level.

This argument is partly supported by the very limited research that took into consideration the impact of the nature of technology upon the commercialisation decisions of technology intensive companies. For instance, 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 those 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.

In addition, Shane (2001), looked at the impact of several attributes of new technology (i.e., 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 frequently 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 films than managers' strategic choices.

Finally, it can be argued that RBSOs origin - and particularly the fact that the opportunities being exploited are often derived from (new) scientific knowledge – may provide them with the conditions to fulfil requirements of novelty/quality and generality/pervasivenss of the knowledge underlying their technologies. However, even among RBSOs there is likely to be variety in the nature of the knowledge underlying their technologies. Thus, it is expected that differences at this level will affect the decisions on the commercialisation mode.

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3.1.2 The impact of nature of knowledge on RBSOs strategic decisions

The limited consideration of the impact of the nature 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 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 above 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, as we will see below, 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:

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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 also 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 of 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.

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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.

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Maybe the most comprehensive analysis was the one 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; that SMEs which lack complementary assets are more likely to license their technologies, but that 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.

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This research have put particular emphasis on identifying and delimiting a strategy that focuses on technology trade and on distinguishing it from strategy(ies) focusing on product/service development. But while the distinguishing element between what can be generally describe 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 depends on the approach adopted by the various authors regarding 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 one key element in 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 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; Fosfuri, 2006).

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 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 them from expropriation. It also has risks, derived from engaging in contractual

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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 knowledge. 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 provides 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 for 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

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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:

Hip 2a: *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 eventual difficulties in enforcing patent rights on products being commercialised - and thus give relatively less importance to patents and/or attribute them different roles. Therefore, in addition

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to assessing whether presence of patents is effectively more important to firms operating in TM, 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.

Hip 2c: *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.*

The impact of RBSOs origin on the appropriability conditions should also be taken in consideration. It can be argued that when the new firm is exploiting knowledge that was directly transferred from academic research, there is a greater possibility that its technology is patented. In fact, not only scientific knowledge is, in principle, 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 (the entrepreneurs often being the patent inventors), granting it IP protection from start-up. Given the information asymmetries that characterise 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:

Hip 2d: *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) a number of non-technological assets (physical assets or knowledge and skills) that are necessary to sell a complete product or service: such as manufacturing capacity; marketing, sales and distribution; regulatory knowledge (Teece, 1986). Access to these assets can be done in different ways: market acquisition, building in house, alliance with the owner of the asset (Colombo et al, 2006; Gans and Stern, 2003; Shan, 1990).

Those assets may be generic and supplied in 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, 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

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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 or, even if some applications are foreseen, requiring extensive transformations 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*. Such difficulties 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). The 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

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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 managerial 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)[2].

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 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

[2] 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).

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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 (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 mobilise through its networks (Elfring and Hulsink, 2003). Firms find it easier to build or gain access to assets in areas in which there is already 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.*

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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*

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4. CONCLUSIONS

This paper addressed the commercialisation decisions of research-based spin-offs, focusing on the case of companies that choose to target the market for technologies. The objective was to provide a comprehensive analytical framework, that contributed to explain the conditions behind the emergence of a model of entrepreneurial behaviour that 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.

Combining insights from two streams of literature - economics of technological change and strategic management of technology - we discuss the conditions that can influence firms' ability to pursue with this strategic orientation; and advance 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. In subsequent research we intend to produce empirical evidence to test the theoretical hypothesis formulated.

This paper 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). Still, the fact that the focus of our research is on one particular set of technology-based companies – RBSOs - enables us to take into closer consideration the specific characteristics of these companies, which are not addressed in other research and which are likely to affect their strategic behaviour. This is particularly relevant if we consider that some factors hypothesised to influence the IP-based model of behaviour encompass features often associated with the RBSO – namely with characteristics of two of its main assets: the technology and the entrepreneur – thus 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 provides some theoretical 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 innovative system, which 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

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knowledge partners, suppliers and clients (both private and public). It is therefore relevant, both from a research and from a policy standpoint, to consider more attentively this model of RBSO behaviour and to provide explanatory evidence on the conditions that favour its adoption and that make it a viable business strategy.

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