Innovation in Business Markets: the case of emerging technologies

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Abstract

Most existing innovation theories imply departure from an established industry recipe. Although they offer good insight into established sectors and companies, they are less suited for understanding high tech sectors and the start-up companies in them. Through a series of in-depth interviews in three high tech sectors (biopharmacy, medical devices and nanomaterials) we construct an alternative model that is better suited to this end. It regroups companies according to the processes of productification and strategic shift and does not presume an industry context or recipe to be present. This new model pays special attention to the role of networks in the innovation processes.

1. Introduction

In this paper, we study the case of innovation in business markets through the lens of emerging technologies. Traditionally, the IMP-group has been researching innovation in business markets by looking how technologies can be acquired, managed and developed within the context of continuing business relationship between sellers and buyers (see for instance, Ford et al. 2002). In this view, innovation is not seen as being dependent on just one single new technology developed by one company (Gadde, Huemer and Håkansson 2003) but on the level and nature of the interaction between companies in business networks.

Whereas mainstream IMP research has been focusing on the innovation processes within the context of established companies, we focus on start-up companies dealing with emerging technologies (such as nanotechnology and biotechnology) and/or with innovations in high-tech business-to-business markets (such as medical devices). The situation of high-tech start ups is rather specific. Not only do they have to combine technological advances with innovation in market or strategy approaches, they also operate in a situation that lacks an industry context. These two elements explain why existing theories are less adapted to explain the processes at work in high-tech start ups.

This paper inductively develops a more adapted approach to innovation in high-tech sectors. Based on the results of in-depth interviews it proposes a model of so-called entrepreneurial innovation and links it to important considerations on the role of networks.

The next section provides an overview of the current approaches to innovation and integrates them into one framework from which we derive the main research questions. The third section introduces the research setting, the methodology and the general findings. This leads to an adapted model of entrepreneurial innovation in the fourth section. Here we also discuss the role of networks in this adapted approach. Finally we conclude with implications for entrepreneurs, investors and policy makers involved in high-tech start ups.

2. The traditional approaches to innovation

Existing innovation literature has, to a large extent, been involved with the situation in well-defined, existing industry contexts. There appear to be two main streams of thought. The first one could be called the technological innovation school, the second one the strategic innovation school. Although they have remained largely separated, we will integrate them here into one framework.

2.1 Technological innovation

The dominant stream of literature is concerned with technological innovation. Basically it claims that sectors and industries evolve together with the technologies on which they have been built.

Technologies evolve according to an S-shaped curve (Foster 1985; McGahan 2000) that begins with its emergence, evolves into a high-growth phase where it overtakes the existing dominant technology and finally flattens out and even declines when maturity sets in and a new technology (a new S-curve) emerges.

The basic argument for innovation lies in this S-curve theory. As long as evolution takes place along one curve, there are no major shocks in the evolution and we witness incremental innovation (Rycroft and Cash 2002). When there is a more fundamental development, a transition to a new S-curve occurs and the innovation can be called radical.

Further developments extended the S-curves into a punctuated equilibrium model of technological evolution (Anderson and Tushman 1990; Henderson and Clark 1990; Suarez and Utterback 1995; Schilling 1998; Tergarden, Hatfield and Echols 1999; Koberg, Etienne and Heppard 2003). Over the course of time, an industry goes through periods of relative stability where one technology is dominant over the others. Innovation during such periods adds on to the existing dominant design and is therefore incremental. When the technology matures and new superior alternatives gain some foothold, an era of ferment sets in. During this period, there is intense rivalry between technologies to achieve dominance and innovations are often far more radical. When the battle is over, a new dominant design is established and another era of incremental progress sets in.

2.2 Strategic innovation

Although the technological innovation school has received most attention in the past, a group of researchers became aware of companies that outperformed their competitors without relying on a technological advance. Rather they made sense of their environment and industry differently than their competitors (Weick 1979, 1995).

It appears that companies in the same industry have a common frame of reference that guides the decisions of their management. This frame has been referred to as the dominant logic (Prahalad and Bettis 1986; Bettis and Prahalad 1995). Originally it was seen as the mindset of top management. Later on it became clear that the dominant logic was expressed through all the corporate level functions - like allocating resources, coordinating business units and monitoring performance (Grant 1988) – and that it therefore not only influences decisions by key individuals, but also the behaviour of the whole organization. Because organizations learn from their "shared experiences" (Huff 1982) the dominant logic evolved further from an emergent property of an organization into a lens through which the majority of players perceive the industry they are in (Von Krogh and Roos 1996; Von Krogh, Erat and Macus 2000). This strategic frame (Huff, ibid.) determines what information from the environment will be reacted to. This means that strategic decisions that fit within the frame are more likely than others for most companies in the industry.

An important implication of this line of thinking is that there are gains to be had from deliberately thinking out of the dominant logic (Kim and Mauborgne 1997; Crossan and Bedrow 2003; Porter 1996; Markides 1997, 1998). This strategic innovation then need not be based on a technological advance, but rather on finding a unique, unoccupied strategic position in the industry.

It appears that IMP interest is mostly in this field as it is more related to marketing and strategy than to technology (see, for example, Subroto, Sivakumar and Wilkinson 2004). The research agenda focuses not so much on one isolated firm's unique strategic position, but rather on the networks of firms and how their relationships can confer unique positions and advantages (Gadde et al 2003).

2.3 A synthesis

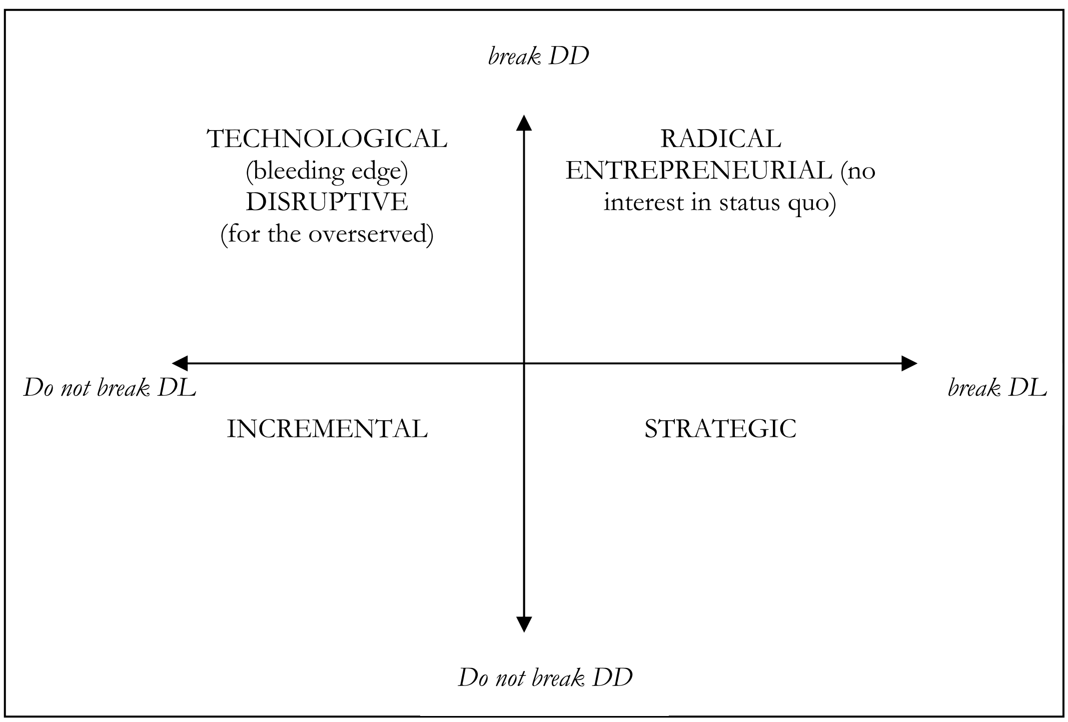
The two streams of research described above have remained largely separate in the past. Nonetheless it appears they both bear quite some similarities. On the one hand, the dominant design school shows that technological innovations are not necessarily better, but different. In the end they replace existing ones. From a dominant logic point of view, on the other hand, successful competition is built on being different from the pack.

Dominant design and dominant logic can be considered as being the constituents of an industry recipe (Spender 1989). This recipe influences to a great extent the actions taken by executives in the industry. Therefore there is gain to be head from deviating from this recipe, either technologically by breaking the dominant design component of it, either strategically by breaking the dominant logic. This gives rise to four basic innovation types as depicted in figure 1.

2.4 Research questions

Based on the framework in figure 1, we can formulate the central research question of this paper:

"What are the barriers for entrepreneurial companies evolving away from incremental and towards technological and/or radical entrepreneurial innovation?"



This can be further specified in two sub-questions:

"Are those barriers the ones indicated in figure 1: crossing from incremental into technological and from technological into radical entrepreneurial innovation?"

and

"What is the role of networks in this process? Is it the same in all cases?"

Figure 1: The classical approach to innovation

3. Research setting and methodology

To provide an answer to the questions raised by figure 1, we conducted in-depth interviews in three high-tech sectors. The contexts of these sectors are quite different from established industries and from each other. Therefore we will introduce them in the first section. The next section then presents the overall procedure we follow and the interview guide we use. Finally we discuss the findings.

3.1 Research setting

The research is being conducted in three high-tech sectors: biopharmacy, medical devices and nanomaterials.

Biopharmacy regroups activities of seeking and developing drugs based on biological rather than chemical insights. By using the growing understanding of basic cell functioning, it holds the potential for cures to currently untreatable diseases. Although growth has been explosive in the second half of the nineties and there are some very successful products on the market, it remains a very high-risk sector with very high failure rates (Ernst&Young 2003). As the knowledge needed is so different from classical pharma, activity mainly takes place in small specialized start-up companies. They need ties to other parties to face the risk, complexity and costs of development processes that take up to 10 year, cost EUR 500-800 million and can stall at any given time with no possibility of recouping investment.

Medical devices are the appliances used in healthcare. In principle they do not enter the body although there are some substances used as tracers that can be classified as devices as well. Compared to the other fields, medical devices is a fairly mature area made up of both large corporate players and a score of start-ups. Nonetheless, there is a lot of high-tech development going on leading to very advanced products. The main problems are on the one hand the market fragmentation and local habits and regulation and on the other hand the increasing price pressure that drives down margins.

Nanomaterials are materials that are built up of extremely small particles that are only a few billionths of a meter in size. At this scale new and interesting properties appear that are not exhibited by the same materials at larger measurement levels. Most of the possibilities have been thought of in a seminal book in the eighties (Drexler 1986), but they still remain unrealized today. Although progress is being made continuously and a handful of companies have been created, nanotechnology remains to a high extent a scientific discipline and not a commercial sector.

3.2 Methodology

After a first screening, a number of experts in each sector have been contacted. After an interview had been granted, we collect background information to get a better understanding of the organization and its functioning.

The interview itself typically lasts 1h30min and is structured according to a standard interview guide, which we will discuss below. Everything is transcribed and condensed into contact summary sheets that we fed back to the interviewees (Miles and Huberman 1994).

Afterwards, the transcripts are coded and check-coded to eliminate interviewer bias. The coding list we use has been immediately derived from the generic interview guide. The coding facilitates pattern matching across interviews, which results in an overview display. This display then plays a major role in the analysis of the applicability of the model in the high-tech sectors under study.

All in all ten interviews have been conducted up until now. In the three sectors mentioned above, entrepreneurs, venture capitalists and innovation professionals all over Europe have generously donated their time. Table 1 provides an overview.

table 1: An overview of the interviews

# interviewees	Venture capitalist	Portfoliocompany	Innovation prof.
Biopharmacy	3	/	1
Medical Devices	2	2	/
Nanotechnology	1	/	1

3.3 Interview guide

The semi-structured interviews all follow the structure of the generic interview guide. It consists of three main parts: questions on the organization of the interviewee, his or her perception of the current state of the sector he or she is in and finally a probe into what is perceived as new or frame-breaking initiatives.

The questions on the current state of the sector were regrouped into three categories: the structure, technological aspects and strategic aspects.

Questions on the structure of the sector are theoretically grounded in Porter's view of strategy (1980, 1985). Both the structural barriers to competition and the value chain are scrutinized. As the goal of this part is to build an overview of the sector with the interviewer, it is not being reported here. The technological aspects are built on the notions of dominant designs and their implications for innovation and product development. The strategic aspects finally explore the existence of dominant logics and their implications.

3.4 Findings

The findings are discussed according to the structure of the interview guide. Therefore we first look at the existence of a dominant design, then that of a dominant logic, the linkage between both and finally the perception of frame-breaking ideas. This is summarized in table A-1 in annex.

Current state of technology and dominant design

In biopharmacy, the respondents could not indicate a technology or a design that was dominant. Rather, there were a number of approaches to a wide range of problems. One VC formulated it very bluntly: "*No, there is absolutely no underlying technology whatsoever on the market*."

In the medical device field, however, there appeared to be some kind of dominant design at the very general level: most devices seemed to be based on a microprocessor.

"You have what you could call a biochip. You put some blood on the chip and it is automatically analyzed. (…) It can be used for a lot of purposes in the diagnostic field. It can be used in a lot of different settings."

Nanomaterials showed a mixture of both. On the one hand there is no dominant design in the fabrication of nanoparticles, but on the other hand there are some applications (like filters) where the use of nanotechnology challenges the existing design. However, there are very few nanocompanies involved in activities other than the pure creation of nanoparticles. "*There are many different ways to get to nanoparticles. You cannot say that there is a technology that dominates the other ones. (…) You always have to look at the very special application*".

A closer analysis shows that sectors or companies with no dominant design approached technology from the point of view of the underlying science base (biopharmacy, nanotechnology), whereas the sectors with a dominant design used the application area and the market as their point of reference (medical devices). This opposition between relation to the science base versus relation to the application level will be elaborated upon later in this paper.

<u>current state of the market and dominant logic</u>

From the point of view of the dominant logic we perceive a similar division in two groups. In biopharmacy and nanotechnology, the reported logic related entirely to the development process a start-up company goes through. This is reflected in a thought by a VC: "*Nowadays – for a good partnership – you have to do clinical phase I and II. Three years ago it was possible to partner a product even at a very early development stage"*. In nanotechnology, the situation is very similar. Moreover the perception of business reality was not positive. "*Actually all this* *nanotechnology is still research, but before we see anything emerging from it – it may at least take another ten years. And therefore it is very difficult for those small companies. They don't have ten years*". Or to summarize it concisely: "*The danger is that it is an empty box*". The logic thus relates more to science and technology than to a business setting.

Again, the medical device area is different. The dominant logic takes on its more traditional meaning as it has to do with the market structure and the space companies compete in: *"It is a situation almost all companies are in now: you have to be much better and definitely not more expensive (…) If you want to have success, a really successful growing medical device company, then you need a medical device where you also need consumables".*

In summary, the logic in biopharmacy and nanotechnology is more concerned with how a start-up company should develop from the scientific underpinnings into a commercial venture, whereas in medical devices it has to do with how to successfully compete and approach the market.

<u>link technology-strategy</u>

Despite the differences mentioned above, the focus on technology in all cases needs to shift to and be consistent with a focus on the market.

This transition can often not be accomplished by the portfoliocompany on its own. It needs to seek support in its network. The most likely partner in this case is the venture capitalist "*From the university viewpoint it might be interesting to see that this technology can be developed. But from* *the business standpoint, there has to be a market. Definitely. And that is where it is all about when we are talking about venture capital.*"

VCs indeed play an important role in high-tech companies through the provision of capital, and by influencing the decision making and strategic directions of the companies they invest in (cf. Nagtegaal 1999).

<u>frame breaking initiatives</u>

Respondents in the different sectors and positions agreed more or less on the technology-strategy link: really innovative initiatives reshuffle the existing technology-strategy configuration to some extent.

It is important to note that it is not just about some combination of technology and strategy, but about reshuffling *to some extent.* Too little change leads to incremental improvements that reinforce the existing situation but may not lead to real breakthroughs. Too much change on the other hand meets with major resistance from the market and is bound for failure. This was also expressed by one venture capitalist: "*I think the ideal situation is where you have a product with great advantages. Not something changing the entire world, but I mean an improvement - a definite improvement.*"

4. Discussion

The findings from the interviews suggest that existing approaches to innovation are less adapted to the specific context of high-tech sectors. This is mainly due to a lack of a context – what we have called the industry recipe. Based on this notion of a lack of context, we see two different groups of high-tech start-ups.

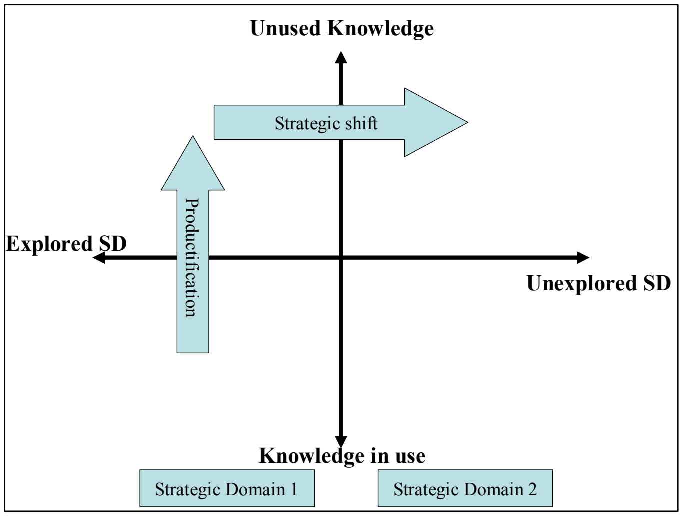
The first group – which contains biopharmacy and nanotechnology in our study – uses the scientific discipline it originates from to define itself. Companies therefore address a potentially vast domain of products and markets, but completely lack an industry context to work in. In such a pre-market situation there is no dominant design to challenge and dominant logic only expresses ideas about the development trajectory from science to business. Not surprisingly the high uncertainty leads to high risk and an elevated failure rate.

The second group is not working from science to a first application, but takes technological findings that have already resulted in a first product to new and more defined markets. By providing an intrinsic value-added technology and combining it with appropriate management (cf. Chesbrough, 2004), these companies establish themselves either in the market where they introduced their technology at first, either in a completely different market. In the latter case, it is not possible to talk about a dominant design either because the industry context is temporarily unclear while the company is shifting (Munir and Philips, 2002; Munir, 2003). The dominant logic on the other hand is more "standard" in that it refers to the markets that should be addressed or how should be competed.

4.1 An adapted model of entrepreneurial innovation

Because there is no industry context or recipe to fall back on, the model in figure 1 is less suitable for thinking about entrepreneurial innovation in high-tech sectors. Figure 2 suggests alternative model that departs not from dominant logic/dominant design, but from the opposition between used and unused knowledge on the one hand and that between explored and unexplored strategic domains on the other hand.

Figure 2: An adapted model of entrepreneurial innovation



Strategic domains not only encompass a market, but also the research that may lead to products on that market later on. As such the four quadrants in figure 2 define two strategic domains.

The lower-left quadrant thus defines the domain that mostly coincides with an existing market and the applied research in that same area. The upper-left quadrant is what the future may bring for this market. Here the first results of fundamentally new scientific knowledge are being introduced, but they do not leave the context in which they have been created. Many high tech start-ups are in transition from the lower-left to the upper-left quadrant. It is this process of productification that determines their state of being. When the process nears completion, they become part of the market in that domain and the existing models become applicable. This is typically the situation biopharmacy and nanotechnology companies are in.

The second group of high-tech start-ups are already past productification. They apply new knowledge and scientific findings that have already resulted in a first product, to existing markets. Because the knowledge is still relatively new and unused, they operate in the upper-left quadrant. As indicated earlier, many companies will craft a position in the strategic domain they are in and stay there. In case the introduction of the new technology is sufficiently fundamental and accompanied by an appropriate strategy and management, a strategic shift may occur to another strategic domain.

Two remarks have to be made. First of all it is clear that the strategic domains in this model need to be defined depending on the situation one wants to analyze. By picking the relevant domains insight can be gained in the trajectories start-up companies go through.
Secondly during both productification and strategic shift there is a change in focus from technology to strategy and market approach.

4.2 The role of networks

One remarkable feature of the model presented here is that it recognizes the importance of two types of intercompany networks in the transition processes.

The first type is the most obvious and could be called the explicit network. As mentioned before start-ups companies can hardly ever handle to transition from technology to market orientation on their own. Therefore input from external parties is needed.
Venture capitalists play a major role in the explicit network. They not only provide capital, but also management advice and often take up an active role in the management or governance of the company (Fried and Hisrich 1995). Because their main concern is making good returns on the money they invested, they urge the start-up to take a more commercially oriented approach and provide an important impetus in the push for more strategy and market focus.

Besides venture capitalists industrial partners appear to be important. This fact has been especially well established in biopharmacy, where strategic alliances between small drug development companies and large pharmaceutical players are standard (Niosi 2003). Industrial partners are not only important because they provide money in exchange for licensing rights when the start-ups churn out successful products. They may also be the source from which the company has been spun out. Many large players have new venture divisions that develop and nurture promising projects until they are ready to evolve into a company of their own right.

The explicit network not only ties commercial players together. A very important link in the high tech arena is the one between academia and start-ups. University laboratories are one of the major sources of high tech start-ups (Vohora, Wright and Lockett 2004). The founders are very often researchers who have left academia to manage a commercial venture or they are (which is more likely) closely involved through an advisory board. Note that this close relationship may prove to be both beneficial and detrimental. On the one hand it ensures further fundamental development and input of new ideas is maintained. At the same time it may prevent the start-up from evolving towards a real venture in the commercial arena.

Another kind of network is also taken into account in our model: the implicit network. In many (not to say most) cases new ventures fail (Manigart, Baeyens and Van Hyfte 2002) and the process they are in (productification or strategic shift) stops. Their technology and product can however be picked up by another start up that then continues more or less from the point where the previous venture left off. In other words: the focus of our model is not so much the individual company but the transition processes, which can be fulfilled by a single company or by several independent companies that build upon each other. These companies have no formal ties which we can classify as a network, but they are linked through the ongoing project they all work on at different points in time. This is what we refer to as the implicit network.

5. Conclusions and further research

This paper provided a first attempt to develop a model that is more suited to explain entrepreneurial innovation in high tech sectors. Through in-depth interviews with venture capitalists, entrepreneurs and innovation professionals it was shown that the existing literature in this field is less adapted to dealing with situations that lack an industry context. By introducing the notion of a strategic domain we provide an adapted model that takes into account the specificities of high tech sectors. It regroups start ups in those sectors according to the transition process they are in: productification and strategic shift. Although both processes involve a change from technological to market thinking, they pose different problems and require different skills from the company and its network (especially the VC).

The research described here leads to two preliminary propositions that are guidelines for future work:

- Firms in the productification process work on more fundamental innovations than those in strategic shift. Therefore their risk is more elevated, but so are the potential rewards.
- VCs have a different role in each of the processes. During productification they mainly have to provide the commercial reflex and the impetus to evolve from a

scientific to a commercial mindset. During strategic shift they have to help the company come to grips with the new strategic domain and markets it enters.

Any subsequent work will, as an anonymous reviewer correctly pointed out, have to be more focused and tackle only one of the topics suggested here. The most logical avenue right now seems to be to further develop a rigorous definition and (process) model of entrepreneurial innovation in high-tech sectors that takes this paper as a starting point (i.e.: if the traditional approach does not yield sufficient insights, what other models can we use to study the process of entrepreneurial innovation?)

Although the focus will get more narrow, the model building will most likely require an enlargement of the methodology. The interview and case study approach has to be complemented by more quantitative approaches that are more suited to constructing structural models.

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