Harnessing the potential of emerging technologies: a review of key development and commercialisation strategies[1]

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Abstract

Emerging technologies such as biotheraputics are widely view as the source of new types of competitive advantage. Despite their huge potential, gaining advantages from these technologies requires adopting different types of managerial skills and insight than those utilised in the context of incremental improvements. This makes established firms particularly vulnerable to the challenges of these technologies. This paper reviews the findings of selected studies, to identify key issues in the development and commercialisation of these technologies.

Keywords :

Emerging Technologies , Discontinuous Innovations , Opportunity Recognition, Radieal Product Innovations

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1- This paper is part of an ongoing study

1. Introduction

Emerging technologies -e.g. gene therapy, electronic commerce and micro machines- seem to enjoy widespread popularity among scientists as well as policy makers around the world who see a great potential in these technologies to create new markets and change the basis of competition in existing industries (Adapted from Day and Schoemaker, 2000a).

According to Levitt (1960; cited in Lambe and Spekman, 1997) companies that fail to respond to the prospects of radical product innovations can expect serious consequences. For them, potential outcomes range from the loss of an important opportunity to a significant shrinkage in the market share.

Emerging technologies are science-based innovations that encompass both discontinuous technologies derived from radical innovation e.g. biotheraputics as well as more evolutionary technologies such as the Internet (Day and Schoemaker, 2000a).

Although developing countries are technologically lagging behind the developed world certain characteristics of emerging technologies attract them on their attempts at technological development. It is held that certain emerging technologies e.g. biotechnology and genetics can be rapidly developed in developing countries given the existence of low-cost technical and scientific human resources in these countries (APCTT, 1986).

Focusing on the firm level dynamics, this paper reviews key managerial challenges in the development and commercialisation of emerging technologies to gain a competitive advantage.

In this paper, after a brief introduction to the definition and dimensions of radical innovations, key issues in the commercialisation of radical innovations is discussed, strategies for stimulating radical innovations in large companies are introduced and finally a section discusses the pitfalls that established firms might encounter when faced with the challenges of emerging technologies.

2. Definition and Dimensions

Researchers have utilised an expanding set of terms to organise the concept of innovation into manageable subsets: evolutionary versus revolutionary, incremental versus discontinuous, and sustaining versus disruptive. These pairs of terms refer to the bimodality of innovation (Mascitelli, 2000).

The term "discontinuous innovation" is typically utilised to refer to radically new products that entail dramatic leaps in terms of customer familiarity and use. Aircraft, cars and PCs were all discontinuous innovations when they were first introduced (Veryzer, 1998).

In the real world a broad continuum can be visualised that links the dichotomous concepts of continuous and discontinuous innovations. In addition to bimodality, the second common attribute the pairs of terms refer to is that innovations are either predictable or original (Mascitelli, 2000).

A product can be discontinuous (or perceived as discontinuous) along three dimensions: product benefits, technological capabilities and consumption or usage pattern. The first dimension, product benefits, reflects the new capabilities of the product in satisfying the needs of the customer as perceived or experienced by the customer. The second dimension, technological capabilities, is meant to show the improvement in the way the functions are performed. And finally, the consumption pattern dimension refers to the required change in the thinking and behaviour of the consumer in using the product (Veryzer, 1998).

A product can be new or discontinuous according to one or more of the above mentioned dimensions. For example, while PCs encompassed new technology and required a change in the consumer's usage pattern, the SONY Walkman® did not utilise much new technology but was perceived as a really new product (Veryzer, 1998).

A final point is that, given all the emphasis on discontinuous innovations we should not ignore the importance of the more continuous improvements. Incremental product line improvement are necessary for maintaining leadership but only after gaining it through the more discontinuous forms of innovation (Lynn et al., 1996).

After this brief introduction to the nature and dimensions of discontinuous innovations, the next section focuses on perhaps one of the most difficult and at the same time most important tasks developers of discontinuous innovations should tackle, i.e. developing an understanding of the market for these innovations.

. The market for discontinuous innovations

Perhaps the most difficult task for the developers of discontinuous innovations is gaining an insight into the market for these innovations. All successful discontinuous innovations such as Xerography, the VCR, PCs

and optical fibres have had to overcome the triple uncertainties about the market, the technology, and the timing (Lynn et al., 1996).

In this section we briefly introduce some concepts extracted from the literature that can help the developers of radically new technologies to gain an insight into the market for these technologies. First the concept of "opportunity recognition" is briefly discussed, a "probe and learn" approach to market analysis is introduced and finally factors affecting customer's evaluation of discontinuous new products are discussed.

3-1- Opportunity recognition

O'Connor and Rice (2001) define opportunity recognition as: "the bridge that connects a breakthrough idea to the initial innovation evaluation process which in turn leads to the formation of a formally established commercialisation effort".

A critical task that the developers of radical innovations face is linking advanced technologies to market opportunities. With the markets not yet formed, given the organisational pressures for immediate profitability, maintaining the momentum is difficult (Adapted from O'Connor and Veryzer, 2001).

In addition to the ability to comprehend the implications of disruptive technologies appearing outside the firm, there is also a need for the capability to understand the potential of technologies emerging from one's own R&D laboratory, and choosing the right path to their commercialisation (O'Connor and Veryzer, 2001).

In a longitudinal study of twelve radical innovation projects, O'Connor and Rice (2001) have proposed methods to improve the organisational capability for opportunity recognition. In the following paragraphs we briefly discuss their recommendations.

Articulating a call to action can encourage idea generation and opportunity recognition. If managers express a need for breakthrough ideas, they will probably get a response. A large proportion of the projects in the sample O'Connor and Rice (2001) examined, had followed from management's articulation of strategic intent to grow in a particular technology or market.

Investing in organisational enablers for opportunity recognition is another activity that can help link the opportunity recogniser to internal and external sources of information. Interactions with scientists in similar fields of expertise and related professions were examples of such activities observed in the case studies.

Sustaining attention on the radical innovation project for example by establishing a project oversight board can help protect the project from senior management turnover and organisational change. *Promoting informal networks* to improve awareness and sensitivity to business issues can be another relevant move.

Finally, *developing organisational structure mechanisms* to support opportunity recognisers is another option. There are three types of opportunity recognisers: gatherers, hunters and radical innovation hubs.

Gatherers are passive opportunity recognisers (an example can be a good R&D manager). They must have sufficient scientific knowledge as well as market knowledge. Hunters are active opportunity recognisers. They have a more marketing and business orientation and have a broad rather than a specialist technical background. An important skill they must develop is the ability to express the opportunity to the management in a convincing manner.

Finally, a radical innovation hub is a known home for ideas. The hub's staff can call up evaluation teams, record the evaluations and provide feedback to idea generators. A successful hub needs a staff with diverse experiences, recognition in the organisation as the group that deals with ideas and the skills required for evaluation and articulation of the benefits of new technologies.

According to O'Connor and Rice (2001), the process of initiating a potentially game-changing project from the firm's stock of technical knowledge, appears to be unpredictable, depending on chance, highly motivated individuals and rich informal systems. The initial assessment of opportunity recognisers not only depends on individuals with diverse and distinct skills, but also due to discontinuities in the course of the project, requires multiple waves of opportunity recognition.

In the next subsection, the "probe and learn" approach to developing an understanding of the market potential of radical innovations is briefly discussed.

3-2- The probe and learn process

To explore how companies gain an understanding of the markets for their discontinuous innovations, Lynn et al., (1996) have analysed a diverse set of successful cases. According to Lynn et al., (1996), while conventional market research techniques (e.g. customer surveys and focus groups) were utilised in the cases, only some of the information generated

were useful and the information generated did not have a significant impact on the development of the innovations.

Lynn et al., (1996) observe that the companies develop their products by probing potential markets with early versions of the products, learning from these probes and repeating the process. The initial product did not end the development process but was the first step and in itself was not more important than the following learning and informed subsequent steps.

The probe and learn process consists of three steps: probing, learning and iteration. In the *probing* step, an early version of the product is introduced to an initial market. For example ten years before the first licensed, commercial systems were sold, Motorola introduced its first cellular telephone to sample markets in Chicago, New York and Washington. Although they did not have much appeal because of their large size and weight, they served their purpose. They proved to the Federal Communications Commission that someone other than AT&T could make a feasible cell phone system. Also the company learnt more about the market and customers' needs.

Probing without the *learning* that can follow from it is not meaningful. Motorola learnt from its initial probe that its product was too large and heavy therefore size and weight became performance parameters for the next twenty years.

And finally, probing and learning is an *iterative* process. The firm introduces an early version of the product, modifies the product and marketing approach based on the learning from the experience and tries again.

The conventional new product development paradigm is regarded as a staged, analysis-driven process consisting of six steps: idea generation, screening and evaluation, selection, development, testing and commercial launch (Lynn et al., 1996).

The discontinuous new product development is also multi-phase but is essentially different from the conventional approach. Its logic is more experimental than analytic. This difference stems from the fact that the discontinuous process carries with it more uncertainty. Both the market and the technology are ill-defined and evolving and the two also interact. This, especially in the early stages, makes it almost impossible to predict what product will finally be offered, at what price, to whom, where and when. Finally it should be noted that the probe and learn process is not a process of blind trial and error. It is a process of experimental design and

exploration that takes meaning if conducted in a context with strategic relevance to the firm (Lynn et al., 1996).

3-3. Factors impacting customers' evaluation of a discontinuous new product

Gaining an insight into the factors impacting customers' evaluation of a discontinuous new product can help the development team take appropriate decisions. However, a key point is that customers do not have a suitable frame of reference for evaluating a discontinuous product. It is likely that the important factors in evaluating discontinuous products are different from those for incremental innovations (Veryzer, 1998).

Veryzer (1998) has identified several factors impacting customers' evaluation of a discontinuous new product and based on these finding suggests a number of guidelines for effective management of the development process of these products. In this subsection we briefly review some of his findings.

In a study of seven firms involved in the development of discontinuous new products, Veryzer (1998) has identified the following factors that seemingly impact the customers' evaluation of the new products.

Lack of familiarity

This factor can be related to the product benefit and consumption pattern discontinuity dimensions. Resistance to the product (fear effect) can be the prime effect of this factor. These effects are partly the result of the misfit between the product and the customers' current consumption pattern. Unfamiliarity with the product can also slow down the acclimatisation of customers with the product.

Irrationality

This factor can be associated with all three dimensions of discontinuity i.e. product benefits, technological capabilities and consumption pattern. Unfamiliarity with the product can lead to "irrational" thinking or focusing on "irrelevant" attributes of the product and underweighting seemingly important aspects (e.g. colour of product housing).

User-product interaction problems

This factor also can be associated with all three discontinuity dimensions. Because of changes in product benefits and consumption patterns resulting from these products, user-product interaction can be a critical factor in the customers' evaluation of these products. Problematic

interactions can cause negative product experience due to misunderstanding of the product, increase the time and effort required to familiarise with the product and cause anxiety about the product safety.

Uncertainty and risk

This factor can be associated with the product benefit dimension of discontinuity. Uncertainty about product benefits and the risks associated with the product can lead to resistance to mental adoption. It seems this factor is partly shaped by the product's degree of discontinuity.

Accordance

Accordance refers to the degree of compatibility of the product with the customer's life and the extent of accommodation required. It seems the disruption caused by the product is moderated by the product benefits perceived by the customer. It appears this factor has more to do with the degree of discontinuity along the consumption pattern dimension rather than the technological capability dimension.

Aesthetics

The appearance of the product, can affect the customers' perception of product safety as well as customers' receptivity to unfamiliar products. This factor can affect both the product benefit and the consumption pattern dimensions.

Based on the findings about the factors influencing the customers' evaluation of discontinuous products, Veryzer (1998) proposes a number of guidelines for effective management of the development of these products. These guidelines in brief are as follows:

- With regard to the discontinuity factors, there seems to be range limits on the degree of discontinuousness customers can relate to and the product risks being labelled "ahead its time" if these limits are exceeded. Also whenever evaluation possible, it is important to have the product evaluated on all discontinuity dimensions.

- Even though the voice of the customer is still important, it seems because of the shifts in thinking and the new applications required, the company, at least for the generation and initial development, may have to rely more on managers knowledgeable about advanced technologies.

- Although the vision necessary for these products might not originate from the customers, their input can have three benefits: identifying their

latent needs, identifying product specifications and examining assumptions underlying the product.

- Involvement of market research personnel in customer testing can improve the quality of information obtained. Also, the integration of marketing into the development process has been shown to enhance product development.

- In Veryzer's (1998) study, product ideas originated within the firm rather than from the customers. This might be due to the highly complex technologies involved that were developed in-house. More study is needed on this respect.

4. Strategies for stimulating radical innovations

According to Stringer (2000), because of four reasons large companies face problems in the adoption and commercialisation of radical innovations:

- Economic and strategic barriers in embracing radical innovations because they have to invest heavily in sustaining (versus disruptive) innovations to maintain their large market share

- Large scale and the resulting bureaucratic structures discourage the commercialisation of breakthrough innovations

- Relying too much on internal R&D departments, the majority of which have limited responsibility for the commercialisation process

- Although they have their share of inventors (originators of creative ideas) but face difficulties in attracting innovators (people who commercialise new ideas). These firms do not offer much opportunity for innovators to satisfy their needs for achievement.

Stringer (2000) offers nine strategies that successful innovators use to stimulate innovation in large firms in the remainder of this section we briefly introduce these strategies. The first five strategies are based on the notion of working with existing resources and organisation. The last four strategies involve working with entities outside the organisation.

1) Making breakthrough innovation a strategic and cultural priority

Talking about the need for new products, setting challenging goals, encouraging business units to increase the percentage of revenues from new products, generating benchmarks for measuring the likely impact of radical innovation in the industry and bringing into attention the gap caused by the lack of radical innovations, are examples of activities in line with this strategy.

The problem with this strategy is that it is rarely effective as a stand-alone strategy and needs to be combined with one or more of the other strategies.

2) Hiring more creative people

While there is little doubt that fresh blood can reinvigorate the organisation, such initiatives can be frustrating and expensive.

3) Establishing informal project laboratories

Increasing flexibility and R&D budgets can offer innovators free time to invent. It is also important to ensure that the performance management system does not punish new ideas that do not have immediate payoffs.

The problem with this strategy is that assigning excess budgets and leniency in project approval might not be consistent with what is believed to be good management practice.

4) Creating idea markets in the organisation

Idea markets or knowledge markets are autonomous teams who are after identifying and commercialising radical innovations. These are more difficult to manage than traditional project labs. Rewarding team members might be the most important challenge. Given these issues, it is easier to use idea markets as a source of breakthrough ideas than using it to commercialise the innovation.

5) Becoming an ambidextrous organisation

Advocated by Tushman and O'Reilly (1997; cited by Stringer, 2000) this strategy aims at creating two different organisations under one roof one dedicated to traditional technology and the other to radical innovation.

This dual strategy can lead to conflict between the historically profitable, large units and the entrepreneurial, cash-absorbing units. Keeping the radical innovators completely separate from the traditional units running the core business and leveraging the benefits of the radical innovations for the whole organisation, are some initiative to reduce the chances of conflict. Having a clear vision for the total business is the most important tool they propose for this problem.

The difficulty of altering what is inside the organisation's boundaries [the emphasis of the above five strategies], has recently led established companies facing changing industries to look outside to stimulate radical innovation. The remaining strategies relate to this tendency (Stringer 2000).

6) Experimenting with acquisitions, joint ventures, cooperative ventures and alliances

The first strategy slow companies have tried to adopt is to acquire or purchase radical innovations. If buying was not possible, alliances and hybrid ownership arrangements with innovators were tried (Stringer, 2000).

Lambe and Spekman (1997) have explored the reasons for the increasing popularity of alliances for meeting the challenges of discontinuous technological change (DTC). They have also studied the changing motivations for using alliances during the different stages of the DTC.

The necessity of rapid product development and industry uncertainty are variables that may explain the choice of alliances over mergers/acquisitions. Technology acquired through mergers/acquisitions is more expensive because the firm pays for the desired technology as well as other technologies/assets it does not need. This is also exacerbated when the firm requires technology from multiple sources (Lambe and Spekman, 1997).

A DTC may initially warrant an alliance for technology acquisition but conditions favourable to such an alliance may change. Changes in technology acquisition urgency and industry uncertainty can affect the attractiveness of an alliance. When a DTC occurs, industry conditions are conducive to the use of alliances as a source of technology for new product development. As a dominant product design begins to emerge, motivations for an alliance weakens because of reduced urgency and uncertainty in the industry. With the emergence of a dominant design, initial alliance motivations become irrelevant, making alliances less attractive than mergers/acquisitions or in-house development (Lambe and Spekman, 1997).

Most mergers, acquisitions, joint ventures and other kinds of external alliances have failed to create a sustainable flow of commercial breakthrough innovations. Viewing these alliances as a process of acquiring a product rather than a capability; failure to learn from the alliance or acquired partner; structural and cultural barriers to full realisation of the commercial potential of the acquired technology are some of the reasons (Stringer, 2000).

Although the track record of the innovation-by-alliance strategy is discouraging, it seems appropriate as an overall programme of innovation management. High-technology companies have been more successful in using this approach than large firms in other industries (Stringer, 2000).

7) Engaging in corporate venturing

Refers to creating new businesses that are managed apart from the company's existing business. While these departments receive internal resources they try to treat them as external resources. Although a few companies have successfully utilised this strategy, generally speaking success rate has been discouraging (Stringer, 2000).

Ownership mentality of large firms and the following overemphasis on formal aspects rather than non-codified aspects of the relationship and failure to learn from the ventures, are part of the problem (Block and MacMillan, 1993; cited by Stringer, 2000).

Also the semi-independent status of a corporate venture is not attractive enough for most entrepreneurs (Stringer, 2000).

8) Establishing a corporate venture capital fund

In addition to providing financing to start-ups, venture capitalists offer important guidance by representation on the company boards. Large companies are now experimenting with this strategy by setting aside a pool of money for investment in start-up enterprises in fields related to the company's strategic orientation (Stringer, 2000).

The track record of corporate venture funds is mixed primarily due to the lack of clarity about the mission of the corporate venture activity (Block and MacMillan, 1993; cited by Stringer, 2000).

The loyalty of the corporate venture capital fund to the interests of the parent company can lead to conflicts of interest between the financier and the entrepreneur. Designing an appropriate compensation scheme for venture capital professionals is another problem since the contracts of these professionals is more lucrative and performance-based than other professionals of the parent company (Megginson, 2001).

9) Participating in an emerging industry fund (EIF)

A few far-sighted leading corporations who do not know how their industries will evolve, are investing in a specially created venture capital fund and setting up knowledge transfer processes to learn how radical innovations are being commercialised (Stringer, 2000).

Unlike typical corporate venture funds, an EIF is managed by independent venture capitalists (VCs) and corporate partners leverage their capital by third-party contributions. Although investors seek high economic returns, an EIF is more strategically relevant when corporate investors engage in a knowledge transfer process in which they learn from portfolio companies. The learning process is three-dimensional, behind the scenes and does not interfere with the fund's main objective of generating high economic returns.

This strategy might not work as the sole source of commercially promising radical innovations because it is too arm's-length, too expensive and too risky. However, in combination with one or more other strategies may provide useful information on the future evolution of an emerging industry (Stringer, 2000).

5. Decision traps of emerging technologies

While the emergence of a challenging technology is rarely a surprise, conflicting views on these technologies coupled with the dominance of traditional thinking frameworks, makes established firms vulnerable to four related sequential pitfalls (Day and Schoemaker, 2000b).

The arguments in this section pertain to situations where new technologies are transforming the industry and taking a passive stance would be dangerous. This section briefly introduces the four traps that Day and Schoemaker (2000b) have identified in these situations.

1) Delayed participation

When faced with a highly uncertain situation, it might be tempting and possibly rational to just watch and wait. In addition, the mental models of established firms are effective in tackling incremental innovations and in unfamiliar settings become dysfunctional. There is the danger of ignoring unproven technologies on the grounds that their small markets do not meet the growth need of large firms. For example IBM at first did not see much opportunity in PCs and viewed them as entry systems from which customers would switch to mainframes.

2) Sticking with the familiar

Uncertainty about the viability of some technical solutions and the dominant design that will emerge, make it difficult to choose a technology path. The possibility of choosing a familiar but wrong technology path increases in situations where: previous successful choices lead the firm to seek solutions in similar areas, the lack of capability to appraise the technology causes fear, a proprietary mind-set leads the firm to seek a technology that will lock customers.

The first two pitfalls are rooted in risk aversion and preference for the status quo.

3) Reluctance to fully commit

Concern about cannibalising existing profitable products, bold forecasts and timid choices, difficulty of justifying investments according to traditional criteria (e.g. ROI), focus on current customers and the fact that successful organisations can not handle multiple tasks due to close

alignment between strategy, structure and culture, are factors that can deter an established firm from fully committing to a new technology.

4) Lack of persistence

Even if a firm manages to avoid the above three pitfalls, it is not clear if it will have the persistence to stick with the task. Missing targets is common in the gestation period of a new technology and large companies have little patience for adverse results. The real payoffs of these ventures may accrue after the senior management's retirement, therefore the senior management's strategic commitment might be more important than the financial commitment the company makes.

Day and Schoemaker (2000b) propose four strategies for avoiding these pitfalls that are briefly introduced here.

1) Attending to signals from the periphery

Although initially the signal-to-noise ratio is low, emerging technologies signal their arrival. The first step to decide which signals to scan for, is to define strategically significant emerging technologies. Then the performance potential of the technology is projected and finally the rate of market adoption and the eventual market is estimated.

2) Building a learning capacity

If the information received from the periphery is to lead to insight and action a learning capacity characterised by openness to differing viewpoints, willingness to challenge entrenched mental models and continuous experimentation is required.

3) Maintaining flexibility

The dilemma regarding emerging technologies is that on the one hand, winners are often early movers who commit quickly to a technology path, on the other hand, commitment of additional resources should be subject to attaining certain milestones.

Commitment, if not irreversible, is not necessarily the opposite of flexibility. Initially, it might be desirable to follow multiple technology paths and once uncertainty is reduced and within the organisation a consensus on the appropriate technology path is reached, then full-scale internal development can begin.

4) Organisational separation

To overcome cultural and structural barriers to new ventures, large companies are advised to establish separate organisations for the pursuit of a new endeavour. The degree of separation can be dependent on the magnitude of technological discontinuity, the extent to which the

activities and customers of the two are different and the difference in profitability.

6. Conclusion

The huge potential of emerging technologies as a source of competitive advantage is attracting many companies. However, the inherent uncertainty about both the technical and market aspects of these technologies, means that the path to exploiting the potential of these technologies is fraught with numerous difficulties. Companies can hope that acquiring the necessary skills and insight to manage the intertwined development and commercialisation processes, can reduce their failure rate.

The discontinuous new product development process is essentially different from the conventional new product development process. Here, the learning and the iterative process of product development and probing the markets are of prime importance. These intrinsic differences make the management of these processes a difficult task that often requires the use of multiple strategies and seeking synergies between the adopted strategies.

Companies seeking competitive advantage from these technologies should scan the inside and the outside of the organisation for opportunities that may arise, systematically combine product development with market research and learn from these processes.

In addition, they should adopt a mix of synergistic strategies for the development and commercialisation of these technologies since the complexity of these technologies means that a single strategy might not always be effective.

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