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STRATEGIES TO COMMERCIALISE BREAKTHROUGH TECHNOLOGIES

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In this paper we focus on the different strategies used by companies during the process of development and diffusion of breakthrough technologies. We distinguish three phases in this process and show that, depending on the length of these phases, pioneers might be confronted with completely different scenarios just after the invention of a breakthrough technology. Different strategies to commercialise breakthrough technologies are also distinguished: a mass market strategy, a niche market strategy and a wait-and-see strategy. We show that the result of these strategies can diverge considerably depending on the scenarios. These strategies are studied in detail for the cases of the photocopier, video cassette recorder, digital camera and microwave oven. Several conclusions are derived from the cases. The main actors involved in the development and diffusion of breakthrough technologies change considerably during the different phases. The market adaptation phase is the most turbulent among all phases: many actors enter and leave the market over a relatively short period of time while making substantial losses. Customer segments and user applications also change considerably during the phases. Usually, niche markets emerge first, *i.e.* specific customer segments using the technology in specific applications, which diverge considerably from the mass market applications that emerge later. In our cases, pioneers of breakthrough technologies never create a mass market. The pioneers that do survive stick to their niche market strategy. After the pioneer, multiple entrants adopt a similar strategy but many of them have to leave the market later. Only a small number of them survives, either by consistently adopting a niche market strategy or by creating a mass market. The strategy of the entrants that manage to create a mass market is discussed in more detail. The management implications of these findings are large. Companies should be well aware of which phase they are in; their strategies need to be adapted to the phase of the process, strategies that appear to be successful in the market adaptation phase, for example, can be detrimental in a later phase. The results of the case studies also indicate that most successful actors consistently pursue one strategy.

Keywords: breakthrough technology, strategy, photocopier, video recorder, digital camera, microwave oven

Introduction

In this paper the focus is on strategies to commercialise breakthrough technologies. Breakthrough technologies represent either an advance in technology that is so significant that attainable price/performance ratios are altered dramatically or enable an entirely new kind of application that changes the behaviour pattern of end users (Tushman & Anderson, 1986). Examples of breakthroughs that shifted price/performance ratios include dynamite, in comparison to nitro-glycerine, and strong fibres like Kevlar, in comparison to contemporary fibres. Examples of breakthrough technologies that enabled entirely new applications at the time of their invention include radar technology, laser technology and communication technologies like telegraphy and television.

Developing and subsequently commercialising breakthrough technologies can be very rewarding but is also a risky endeavour for companies. On the one hand, there are potential high gains like achieving a competitive advantage that can contribute significantly to a firm's

growth and profitability (Veryzer, 1998; Kleinschmidt & Cooper, 1991; Booz-Allen & Hamilton, 1982). Breakthrough technologies have been the source of new product categories, new markets and new industries (Christensen, 1997; Olleros, 1986; Abernathy & Clark, 1985; Henderson & Clark, 1990; Tushman & Rosenkopf, 1992). The history of the American company Raytheon, for example, is intimately connected with the radar, Xerox with the photocopying machine and The Bell Company with the fax and the transistor.

On the other hand, it is remarkable how many companies involved in the invention of breakthrough technologies lose out when the technology is applied on a large scale (Olleros, 1986; Pech, 2003). Projects dedicated to breakthrough technologies are risky, expensive, and usually take several years to produce results (Leifer *et al.*, 2000). Technical, market and organisational uncertainties associated with these projects are much higher than with projects aimed at incremental improvement (Burgelman & Sayles, 1986). Two different types of risks have to be combined to assess the real risk that pioneers experience: (1) the risk that an innovation on the basis of a breakthrough technology fails in the market; (2) the risk that the pioneer fails and vanishes although their technology becomes a success in the market. The first risk has been estimated by Crawford (1977, 1979, 1987) for new products in general, *i.e.* both incremental and radical. He concludes on the basis of several studies that the failure rate is consistently around 35%. This failure rate is probably higher for products based on breakthrough technologies. The second risk was estimated by Tellis and Golder (1996) who use a historical analysis approach and focus on products that are known to be successful. They show that 47% of the pioneers that are first to introduce such a product in the market, fail and vanish. Examples of pioneering companies that vanished include Chux (disposable diapers), MITS (personal computers) and the Stanley Brothers (automobiles) (Tellis and Golder, 1996; Olleros, 1996). The combination of these findings imply that the risk for pioneering companies is much higher than the risk for companies introducing incrementally new products.

In order to look at the causes of this risk and the appropriate strategies to cope with it, we will now describe the process of development and diffusion of breakthrough technologies in more detail. We focus on the following questions: Do the actors change during the different phases of the pattern? What strategies do the actors adopt? What can we learn from those actors that do or do not succeed?

We use a multiple case-study approach for this research. A case study is especially appropriate for this type of exploratory research. It has a focus on documenting the phenomenon within its organisational context, exploring the boundaries of the phenomenon, and integrating information from multiple sources (Eisenhardt, 1989; McCutcheon & Meredith, 1993). This approach allows us to understand the phenomena beyond each individual firm's context and increases the possibility of generalisation of observations (Eisenhardt, 1989). The development and diffusion of four products based on breakthrough technologies are studied and analysed. The photocopier, video cassette recorder, digital camera and microwave oven are selected as cases. These cases are selected because of the availability of well-documented literature and the general expertise of the authors with these technologies. We will show that these cases have considerable similarities like multiple actor

involvement, long lead time to large-scale diffusion, and the changes in subsequent market applications.

In the next section, we discuss the phases in the process of development and diffusion of breakthrough technologies and explain why this process involves considerable levels of risk for companies. In the third section, the result of three strategies is described using different scenarios. The results of our case studies are summarised in the fourth section. Conclusions and their managerial implications are discussed in the last section.

The Process Of Development And Diffusion Of Breakthrough Technologies

The diffusion of products incorporating breakthrough technologies shows a remarkably similar S-shaped pattern for many cases. The diffusion of many (tele)communication appliances also follows this pattern (Miles, 1988; Rogers, 1986; Williams, Rice & Rogers, 1988). This similarity seems to imply that the prediction of market results is relatively straightforward and the risks are relatively limited. There are at least two reasons why this S-shaped pattern does not reflect the actual risks experienced by pioneering companies. Firstly, the S-shaped pattern shows the summed sales of a specific type of product from all the companies, and not the increase/decrease in sales per company. The pioneering companies have to attain or defend a market share vis-à-vis an increasing number of competitors that enter the market later. Secondly, the empirical results show that the process of development and diffusion begins much earlier (Ortt & Schoormans, 2004) and that the S-curve is only the last phase of a longer, difficult to predict process. The invention, *i.e.* the demonstration of the technological principle, is often made decades before the start of the large-scale diffusion. The first market introduction also commonly takes place years before the start of large-scale diffusion of a technology in a mass market. The process preceding the large-scale diffusion is much more erratic and therefore more risky than the S-shaped pattern.

Ortt and Schoormans (2004) propose a model with three phases to describe the entire process of development and diffusion of breakthrough technologies: the innovation phase, the market adaptation phase and the market stabilisation phase. The innovation phase comprises the period from the invention of a technology up to the first market introduction of a product incorporating the technology. The second phase, referred to as the market adaptation phase, begins after the first market introduction of a product on the basis of a breakthrough technology and ends when the diffusion of this product takes off. After the first introduction, instead of a smooth S-curve, in practice an erratic process of diffusion may occur (Clark, 1985). The diffusion is often characterized by periodic introduction, decline and re-introduction of multiple products in multiple small-scale applications (Carey & Moss, 1985). The third phase, referred to as the market stabilisation phase, begins when the diffusion of a product on the basis of the breakthrough technology takes off and ends when the technology is substituted. In this phase, the diffusion of a product mostly resembles an S-curve. Similar

phases are distinguished by Agarwal and Bayus (2002) and Tushman and Anderson (1986). A graph showing the three phases is given in Figure 1.

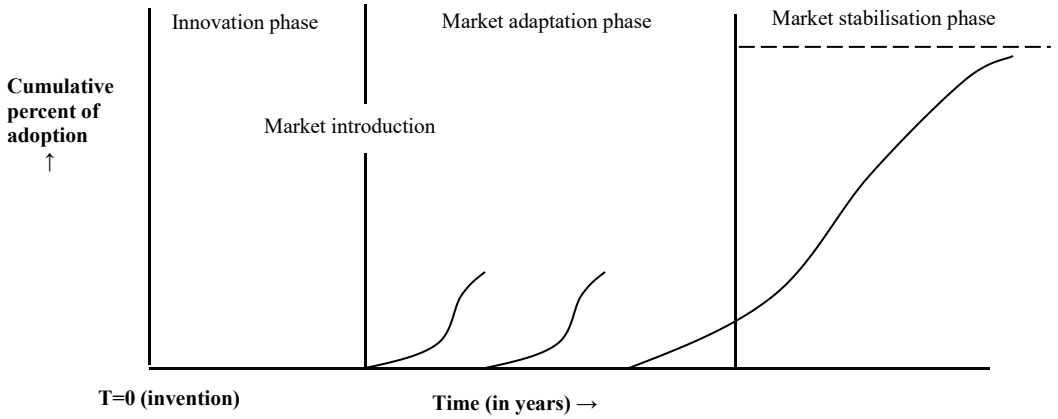


Figure 1: Three phases in the diffusion process

An overview of essential milestones in the process of development and diffusion of the photocopier, video cassette recorder, digital camera and microwave oven is in table 1.

Table 1: Milestones in the process of development and diffusion of the products in our cases

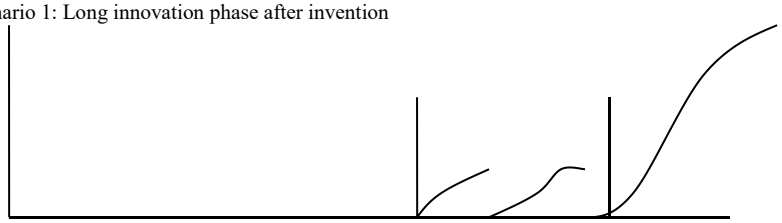
Cases	Invention	Length Innovation phase	Market introduction	Length Market adaptation phase	Diffusion takes off	Length Innovation + Market Adaptation phase
Photocopier	1938	11	1949	27	1976	38
Video recorder	1951	5	1956	15	1971	20
Digital camera	1970	3	1973	17	~1990	20
Microwave oven	1945	2	1947	25	1972	27

From the table, it can be seen that the length of the early phases preceding the large-scale diffusion in a mass market took at least two decades for each of the cases. This is quite long, especially if one compares this with the period that patents remain valid (about 18 years). Similar periods have been found by other authors (Agarwal & Bayus, 2002; Mansfield, 1968; Utterback & Brown, 1972).

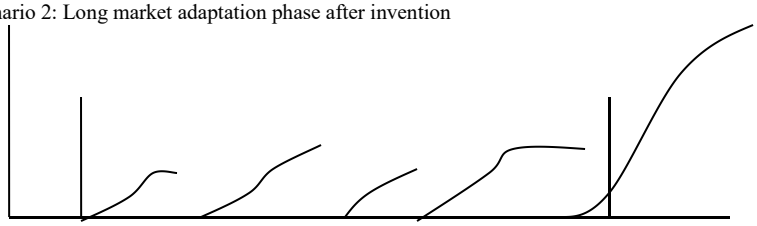
If one compares the length of the innovation and market adaptation phase, the innovation phase is relatively short compared to the market adaptation phase in all four cases. We believe that each phase can disappear in specific situations. These ideas are summarised in two propositions: (i) The phases can vary considerably in length. One or more phases may disappear; (ii) The entire process can stop in each phase.
These propositions convey a more unpredictable process than the S-shaped pattern. In practice, the actors involved in the commercialisation of breakthrough technologies may face different scenarios. After studying the pattern of development and diffusion of fifty breakthrough technologies, we distinguish three important scenarios (see Figure II). Scenario 1 is a situation in which a long innovation phase emerges, which means that it takes a long

time before a product based on a new technology can be introduced in the market. Scenario 2 is a situation in which a product can be introduced shortly after the invention yet its requires a long market adaptation phase, which means that it takes a long time before this product diffuses in a mass market. Scenario 3 is a situation in which a product, based on a breakthrough technology, almost directly after the invention diffuses in a mass market, which means that both the innovation and the market adaptation phase almost disappear. Each scenario is illustrated below using two cases.

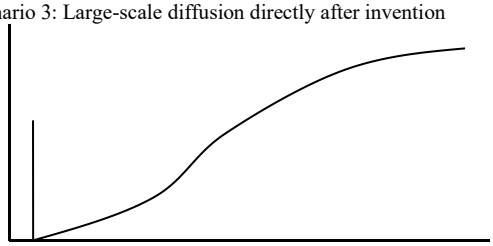
Scenario 1: Long innovation phase after invention



Scenario 2: Long market adaptation phase after invention



Scenario 3: Large-scale diffusion directly after invention



Scenario	Cases	Invention	Length - Innovation phase	Market introduction	Length - Market adaptation phase	Diffusion takes off
1	Radar technology	1904	30	1934	5	1939
	PVC	1838	93	1931	7	1938
2	Contraceptive pill	1927	1	1928	34	1962
	Laser	1960	1	1961	19	1980
3	Dynamite	1866	1	1867	0	1867
	X-ray	1895	1	1896	0	1896

Figure 2: Three scenarios after the invention of a breakthrough technology

Strategies During The Process

Different strategies are available to cope with the uncertainty as explained by the different scenarios. However, the real consequences of the uncertainty can be illustrated by considering the position of a pioneering company, *i.e.* a company that has invented a breakthrough technology and is now considering introducing this technology in the market.

Suppose such a company can choose between three main strategies: a mass market, a niche market and a wait-and-see strategy.

A niche market strategy means that the pioneer invests in small production facilities allowing the production of a specific product, tailored to the niche, and deploying specific marketing and distribution resources for this niche. Empirical research indicates that niche market strategies can be very successful, especially in the case of innovative products (Hultink *et al.*, 1997; De Bruyne *et al.*, 2002).

A mass market strategy means that the pioneer invests in large-scale production, distribution and marketing facilities. Being first with a mass market strategy makes sense, for example, when network effects in the market enable the first mover to establish a strong position in the market quickly (Arthur, 1996). This is the case when the value of the technology for potential customers increases with the number of customers. A prerequisite of this strategy is that some kind of (de facto) standard has emerged and the pioneer can protect the market, for example by means of patents or holding unique knowledge that is difficult to copy.

Wait-and-see means that the pioneer deliberately decides to become a follower. This strategy implies that the company develops the technology, prepares for the marketing and distribution and monitors the market results of competitors until the introduction becomes a commercially viable option. Tellis and Golder (1996) clearly indicate that in the case of breakthrough technologies, smart followers conquered the market and pioneers mostly disappear before the diffusion takes off. Smart followers can decide to keep their knowledge up to date regarding the technology, yet wait with the introduction until this introduction becomes a viable option. Other followers, may choose to invest in venturing, or buy stakes in the pioneering companies in order to be prepared when the technology and the market are ripe (Chesbrough, 2003; Constantinos & Geroski, 2005).

If we combine these three strategies with the three scenarios distinguished in the previous section then the risk to the pioneer becomes visible (see table 2). A mass market strategy requires a very large investment, a niche strategy requires a relatively large investment and a wait-and-see strategy requires a relatively small investment.

Table 2: Result of three strategies in different scenarios

Strategies → Scenarios after the invention ↓	Mass market strategy	Niche market strategy	Wait-and-see strategy
Scenario 1: Long innovation phase It takes a long time before the technology is market-ripe.	The product introduction may be announced but is postponed. The technology may develop further and might take a different form. Stopping the preparations for production, marketing and distribution activities implies considerable losses.	The product introduction may be announced but postponed. Stopping the preparation for production, marketing and distribution activities is less expensive, however, than in the case of a mass market strategy.	The strategy requires relatively small investments to keep the knowledge of the technology up-to-date and to prepare for marketing and distribution. No losses because of a failed introduction.
Scenario 2: Short innovation and long market adaptation phase The technology can be introduced shortly after the invention but it takes a long time of probing before the diffusion takes off.	Sales will be disappointing. The technology and the market may further develop. Adapting the production, marketing and distribution activities implies considerable costs.	Sales will be normal for a niche strategy. Adapting production, marketing and distribution activities is relatively affordable.	On the basis of the results of competitors, knowledge about the market reaction can be monitored. Introduction can wait until viable market applications emerge. A risk is that other competitors may more quickly establish a strong position in the market.
Scenario 3: Short innovation and market adaptation phase Directly after the invention, the diffusion takes off.	Sales increase quickly and because of the available facilities the demand can be fulfilled and the company can quickly gain a strong position.	Sales will be higher than expected. An inability to meet demands can have considerable consequences (loss of market share) unless production distribution and marketing can be scaled up very quickly.	Diffusion takes off earlier than expected. When competitors adopt a niche or mass market strategy it may be difficult to establish a position in the market.

From the table it can be seen that each strategy is optimal for just one scenario. A mass market strategy is the best strategy in scenario 3 where diffusion takes off shortly after the invention. A niche market strategy appears to be the best strategy in scenario 2, where it takes a long period of probing before the diffusion takes off, and a wait-and-see strategy seems to be the best strategy in scenario 1, where it takes a long period before the technology is market-ripe. Potential gains or losses also differ per strategy. Mass marketing is a strategy with a very high gain in scenario 3, and very high losses in the other two scenarios. Niche marketing has fairly high gains in scenario 2 and limited losses in the other two scenarios. Wait-and-see minimises the risk of large losses yet entails the risk that the company is too late when the diffusion takes off. The strategies applied by some of the main actors in the four cases are described in the following section.

Case Studies

In order to decide which strategy to apply, it often helps to look in hindsight at cases that faced similar challenges and learn from them. This approach can reduce the chances repeating mistakes and perhaps, guide managers to make better decisions. In this section, we focus on four cases: the photocopier, video recorder, digital camera and microwave oven. The main actors that developed and supplied these products (table 3), the customer segments and applications that these actors targeted (table 4), and the strategy they adopted in doing so (table 5) are described below.

Actors

By actors we mean the individuals or companies that developed the technology or created a product based on the technology. They play an important role in the development and diffusion of breakthrough technology. Whether a product will be successful or will fail depends, at least partly, on the strategies adopted by these actors. The actors that participated during the different phases of the development and diffusion of the breakthrough technology, namely the innovation phase, the market adaptation phase and the market stabilisation phase are described in table 3. Actors involved before the invention of a technology are also covered. The actors enter and leave (or continue) the diffusion process on a varying timeline. They create a new strategy, or adopt a strategy based on the previous actors. Based on this, we distinguish four different groups of actors - all of which try to supply products in the market. First, the pioneers who are the first to commercialise a new product based on a breakthrough technology. Second, the followers, who copy the business model of the pioneers and also target niche markets. Third, the smart followers who open up a mass market by adopting a different business model than the pioneers do. Fourth, the late entrants that copy the strategy of the actors that created the mass market. The approximate year in which these actors introduced their product in the market is listed in table 3.

Table 3: Actors during the different phases of diffusion of breakthrough technologies

Phases→ Technology↓	Before invention	Innovation phase	Market adaptation phase	Market stabilisation phase
Photo-copier	1934 – 1938 Chestor Carlson works on photocopying process based on electrostatic charge	1938 – 1949 Chestor Carlson, Battelle Memorial Institute (1944), Haloid (1946)	1949 ~ 1976 *Pioneer:* Haloid –Xerox (1949); *Follower:* IBM (1970), Kodak (1975); *Smart follower*: Canon (1968)	~ 1976 - - *Late entrants:* Minolta, Ricoh, Sharp, GE, etc.
Video-recorder	~ 1951 Ampex – a company known for its magnetic recording competence forms a team of engineers to develop video recorder	1951 – 1956 Ampex (1954), Toshiba (1959)	1956 ~ 1971 *Pioneer:* Ampex (1956); *Follower:* Toshiba (1959), RCA (1969), CBS (1968), CTI (1971); *Smart follower:*Sony (1962), Matsushita & JVC (1963)	~ 1971 - - *Late entrants:* Philips, Panasonic, Fisher, Sharp, GE, etc.
Digital camera	~1970 Bell Labs develop the CCD chip in 1969, a vital component of digital imaging	~1970 – 1973 Fairchild markets CCD based digital photography	1973 ~ 1990 *Pioneer:* Fairchild; *Follower:* Texas Instruments (1972), Kodak (1973); *Smart follower:* Sony (1981), Canon (1986), Olympus (~1987), Fuji (1988), Nikon (1988)	~1990 - - *Late entrants:* Kodak (1995), Casio (1995), Epson, HP, etc.
Microwave oven	1940 ~ 1946 Raytheon develops radar appliances and systems mainly for military use	1946-1947 Raytheon Company (1945)	1947 ~ 1972 *Pioneer:* Raythoen Company (1947); *Smart Follower:* Tappan (~1955), Sharp (1962), Litton Industries (1965), Panasonic (1966), Amana -Raytheon's acquired subsidiary (1967)	~ 1972 - - *Late entrants:* GE, Magic Chef, Whirlpool, Norelco, Sunbeam Samsung, etc.

Sources: (Chesbrough, 2003; Constantinos & Geroski, 2005; Lurie & Yoffie, 1990; Magaziner & Patinkin, 1989; Rosenbloom & Cusumano, 1987; Shahida & Ganeshan, 2004; VinayaKumar & Gupta, 2006; Wong & Buzzel, 1983) and the website of individual companies.

Several observations can be derived from table 3. *One*, different actors dominate different phases. For instance, while Bell Labs was the most active actor before the innovation phase of the digital camera, Fairchild dominated the innovation phase, and companies like Sony, Canon and Olympus became active during the market adaptation phase. *Two*, there is a real increase in the number of actors before and during the market stabilisation phase. Many firms including Tappan, Sharp and Litton entered during the market adaptation phase of the microwave oven, and numerous firms such as GE, Magic Chef and Whirlpool entered during the market stabilisation phase. *Three*, the actors dominating a particular phase were active starting from a phase earlier. In other words, the pioneers were already active during the innovation phase, while the smart followers were already active during the market stabilisation phase. Haloid (now Xerox) partly sponsored Carlson's experiments in return for proprietary manufacturing rights and hence was active during the innovation phase. Canon, which opened up the mass market for photocopying machines, was actively experimenting with its new product during the market adaptation phase. *Four*, pioneers never opened up the mass market. Ampex introduced the video recorder for a niche market, but companies like Sony, Matsushita & JVC opened the mass market. Fairchild introduced the first digital camera but companies like Sony, Canon and Fuji opened up the mass market.

Application and customer segments

One of the key features that distinguish *the smart followers* from *the pioneers* is the targeted customer segment. The customer segments aimed by these types of actors are given in table 4. It is important to study these two types of actors in particular because they are the ones that create entirely new markets. Often the risk taken by these actors is high; nevertheless the returns of a successful market creation can also be high, as explained in the introduction.

Table 4: Customer segment – pioneers and smart followers

Application→ Technology↓	Customer segment - Pioneer	Customer segment- Smart followers
Photocopier	Corporate and government offices, catalogue publishers	Consumer mass market - small and medium sized businesses (SMEs) and individuals
Video recorder	Broadcasting industry, schools, police department	Consumer mass market - household use
Digital camera	Space research, satellite and medical applications, news reporter	Consumer mass market - individual/ family use
Microwave oven	Institutional market - hospitals, schools, restaurants, railroad and ocean liners	Consumer mass market - household use

A few observations derived from the table are worth highlighting. *One*, the pioneers target their product at a niche market, which is usually a high end market with specific needs. For example, Raytheon targeted institutional markets with their microwave ovens such as restaurants, hospitals and railroad liners where large quantities of food have to be cooked rapidly. Likewise, Fairchild's digital camera was targeted at space research for customers like NASA. *Two*, the pioneers often stick to their niche market. They keep developing their product to improve its performance in order to serve the needs of their specific customers rather than making a simpler version of their product that can be supplied to a large market. *Three*, the smart followers that create the mass market focus on an entirely different group of customers. Rather than a small number of customers, they target at a larger group of

customers who need a simple product with basic functionality and are unwilling to pay a high price. For example, instead of competing for Xerox's customers who were large governmental or corporate offices, Canon focused on individuals and small businesses that cannot afford expensive photocopiers and need to make just a few copies each day. Likewise, while Ampex focused its video recorder on the broadcasters market, Sony and others focused on the mass consumer market.

Having discussed the customer segment, it is intriguing to see why the actors target a particular segment and how they create value in this segment. In the next section, we focus on the business models adopted by the pioneers and the smart followers.

Strategies and strategic positioning

For all the four cases, we focus on the prevailing challenges during the commercialisation of the technology, the actions taken by the actors to overcome the challenges and the way they handled the complementary products and services. The focus is on the pioneers and the smart followers. Followers and late entrants commonly adopt a strategy similar to their predecessor.

- Photocopier[1] (1934 – 1976)

In the case of the photocopier, the prevailing business model of wet photography and dry thermal processing was like the 'razor' and 'razor-blade' model. A typical machine would cost around $300 (Chesbrough, 2003). Xerox, the pioneer of photocopier machines based on the electrostatic charge process, estimated that the manufacturing cost of their machines would be about $2000, while the variable cost of supplies will remain roughly the same (Chesbrough, 2003). This created a major challenge for commercialisation of the technology: the 'razor' was much more expensive while the 'blade' was no cheaper. The company used a different business model to overcome the high equipment cost. Xerox offered customers a *lease*. Customers needed to pay a nominal $95 per month to lease a machine, and paid a nominal amount per copy. This business model was a bet for Xerox because it assumed that the number of copies would increase considerably, only then was it possible to make a profit. In 1959, Xerox introduced the model 914 to the market.

The 914's business model generated more revenue when more copies were made. This established the logic for Xerox's copier business. The company focused on *high-speed, high-volume* machines. As it was complex to repair these machines, Xerox decided to use its own sales force to lease as well as to repair the machines. This business model did not require partnerships. Xerox manufactured its products, made its own paper to provide optimal feeding and even provided finance for customers.

[1] The majority of the data on the photocopier was collected from (Chesbrough, 2003), (Constantinos & Geroski, 2005) and from *The story of xerography* (www.xerox.com, accessed Feb 1, 2007).

Meanwhile Xerox's monopoly ended abruptly in late 1960s. The Federal Trade Commission forced the company to license its patents to competitors. IBM and Kodak entered this newly created industry. Both these companies focused on high-speed, high-volume copiers, using a business model similar to that of Xerox. Fundamentally, their strategy was to capture a share of Xerox's market – by offering better products or better services at lower prices. Neither of these companies, however, managed to take a decent share in the copier business.

In the meantime, Canon found a way to circumvent Xerox's patent. It designed a distinctive strategic position to enter the photocopier industry. In contrast to Xerox, Canon focussed on small and medium-sized businesses. The company decided to sell its machines through a dealer network rather than to lease them. While Xerox emphasised the speed of its machines, Canon elected to concentrate on affordability and ease of use and repair as its differentiating features. The product design was simplified so customers could replace spare parts and could perform simple repairs. In this way, a dealer network was able to handle the customer contacts. Canon used the 'razor' and 'razor blade' model; it asked a modest 'box cost' for the copier, but earned higher margins on cartridges. Canon outsourced the distribution, service, support, and financing (Chesbrough, 2003). Xerox also attempted to enter this mass market, but learned that the business model was entirely different. In 2001, Xerox abandoned this part of the market, and decided to stick to its original high-end market segment.

- Video recorder[2] (1951 – 1971)

The engineers at Ampex Corporation mastered the magnetic recording technology which helped them to develop a video recorder (VTR) in the 1950s. An experimental VTR was shown at a convention of TV broadcasters in 1956. Although not optimal in design, the VTR was an immediate success: 100 of the $75,000 machines were ordered during the convention (Lurie & Yoffie, 1990). This was primarily because the VTR technology was cost effective and substantially reduced the time required for time-shift programming when compared to its predecessor, the kinescope. Television broadcasters using Ampex's VTR generated enough cost savings to repay the price of the VTR in 11 months (Rosenbloom & Cusumano, 1987). In order to improve the product, Ampex pursued cross-licensing with firms such as RCA and Sony.

Meanwhile, an engineer from Toshiba filed a patent that could circumvent Ampex's VTR technology. However, Toshiba's senior executives failed to understand the potential of this and assigned the inventor other responsibilities. After rejecting Ampex's magnetic tape for a recording video system, RCA opted for a complex video recorder, which it introduced in 1969. However, due to technical challenges and intense competition in its mainstream business, RCA terminated further development temporarily. CBS Labs and Cartridge Television Inc (CTI) also attempted to enter the lucrative broadcasting market with different technologies however they did not succeed due to the complexity of their technology, lack of performance on behalf of the complementary products such as hardware, tape and software and slow progress in their market development. Both the companies left the market and had

[2] The majority of the data on the video recorder was collected from two sources: (Rosenbloom & Cusumano, 1987) and (Lurie & Yoffie, 1990).

to write off substantial losses, CBS lost between $35-40 million, while CTI filed for bankruptcy.

While these firms concentrated on the broadcasting market, three Japanese firms specialising in consumer electronics began to focus on consumer applications for the VTR. Having purchased VTR from Ampex, the National Broadcasting Corporation (NHK) of Japan invited the engineers from the leading Japanese consumer electronics companies to benchmark Ampex's machine. NHK further subsidised the development of a Japanese version of the video recorder. From the late 1950s on, Sony kept a project team working on a home video recorder. Introduced in 1962, Sony's first VTR designed for educational and industrial use was much smaller than the Ampex machine and had a simpler recording system. By mid-1974 a prototype, named Betamax, had been developed. Sony invested in a new plant facility to manufacture the Betamax, setting up a line capable of producing about 10,000 units per month. Having failed to convince its Japanese competitors, Sony proceeded to market the Betamax in Japan in 1975 and in the United States a year later.

Matsushita and JVC, like Sony, began researching video recording in the mid-1950s; all three companies also competed in the commercial VTR market. Unlike Sony, Matsushita and JVC lost money on their VTR projects. Despite the losses, both the companies continuously maintained VTR development efforts targeted at household consumers. At JVC a special video home system (VHS) project team was instructed not to ask what was technologically possible, but rather to determine 'what consumers wanted in a home VCR and then to develop the technology to meet those requirements' (Lurie and Yoffie, 1990). JVC launched its home video recorder in 1976. As Rosenbloom (1987) puts it, persistent technical effort, informed by the lessons of failed innovations, ultimately yielded a design synthesis well matched to the needs of the mass market.

- Digital camera[3] (1970 – 1990)

The charge coupled device (CCD) chip invented by the Bell Labs in 1969 marked a stepping stone in the digital camera industry. The CCD chip, which turns light into digital information, is the heart of the digital camera system. In the early 1970s, Fairchild Semiconductor, a US company with considerable military contracts, marketed this chip for application in the military, in space and in the medical industry. As the chip in itself was extremely expensive and film based photography was widely popular, a consumer application for their product was not envisaged, and Fairchild continued to focus on these high-end niche markets.

The first patent on a digital camera was filed by Texas Instruments in 1972, but it is not known whether they ever built a camera. The first attempt to build a consumer digital camera was made by an engineer at Eastman Kodak in 1975. He used the then-new solid state CCD chip to demonstrate its capability. However, for Kodak, which controlled 90% of the film market and 85% of camera sales, it was a technical exercise and not intended for production.

[3] The majority of the data on the digital camera was collected from (Shahida & Ganeshan, 2004), (VinayaKumar & Gupta, 2006) and the websites of individual companies.

Based upon handheld film camera technology, Sony introduced a filmless camera, not based on the CCD chip, the Sony Mavica. The Mavica was not successful initially, yet it marked the increasing presence of filmless photography technologies.

Digital cameras of today's standard did not appear on the market until Canon demonstrated its RC-701 at the 1984 Olympics. Canon launched this model in 1986 but had only a limited success. Several factors held back the widespread adoption of digital cameras; the cameras cost more than $20,000, the quality of the image was poor when compared to film, and affordable printers to print images were missing. Capturing and printing an image also required access to special equipment such as a frame grabber, which was beyond the reach of an average consumer. The early adopters tended to be news reporters which were willing to pay the high price because digitised images could be transmitted via telephone lines. Poor image quality was offset by the low resolution of newspaper graphics. Within two to three years, Sony, Nikon, Canon and Fuji introduced versions of digital cameras especially targeted at *mass consumers*. The move to digital formats was fuelled by the formation of the JPEG and MPEG standards in 1988 and the parallel development of complementary products such as printers, photo paper and memory sticks. Kodak only introduced its first digital camera in 1995.

- Microwave oven[4] (1940 – 1972)

Originally developed and patented by the Raytheon Company, a US defence contractor, in 1945, the microwave oven utilises a "magnetron tube" to generate microwaves which can heat foods. Within two years, Raytheon had built its first microwave oven, called the Radarange. In keeping with the company's military background, the Radarange was made rugged and powerful. The machine weighed 340 kg (750 pounds), required water cooling and consumed 3000W power. In 1953, Raytheon relaunched the Radarange, with a somewhat streamlined appearance and a book of recipes. It was more successful than its predecessor, selling over 10,000 units between 1953 and 1967. However, these ovens had a very limited appeal for household consumers due to their high price, over $2,000, which restricted their use to institutions such as hospitals, schools and restaurants. Seeing the potential of microwave ovens, other companies such as GE, RCA and Westinghouse got involved, however they did not manage to develop a commercial product until the early 1970s.

In 1952 Raytheon licensed its oven technology to Tappan, which three years later came out with the first home microwave oven, a built-in wall unit. Its magnetron was air-cooled; eliminating the need for a water line. At around $1,200, it was a bit cheaper than the Radarange, but not cheap enough. This institutional market remained small until the mid-sixties when Litton industries, which was licensed by Raytheon to produce microwave ovens, was able to bring down the cost to about $1,000 per unit. The lower cost and Litton's emphasis on reliable products helped to expand that market gradually. Litton gained the lion's share of institutional sales and maintained this position until late 1970s.

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[4] The majority of the data on the microwave oven was collected from (Magaziner & Patinkin, 1989), (Wong & Buzzel, 1983) and the article *The greatest discovery since fire*, Spring 2005, Volume 20, Issue 4, Invention and Technology magazine.

In 1965, Raytheon acquired a new subsidiary, Amana, to introduce the first microwave oven for consumer use. Amana used its expertise in building, distributing, and marketing consumer appliances and applied it to Raytheon's microwave-oven project. In 1969, Litton followed suit and also moved into the consumer market. With the expansion of the consumer market to over 50,000 units sold by 1970, prices came down even more and a microwave oven could now be bought for about $550. In spite of this, the market did not develop as quickly as was thought possible for two reasons: one, it was still expensive buy for household consumers and two, the controversial safety aspects of microwave cooking kept cautious customers at bay. This changed in the early 1970s when the US Federal Performance Standards introduced a microwave leakage prevention standard and when Japanese players including Sharp, Panasonic and Sanyo entered the market with small-sized, low price machines.

The main reason for the relatively cheap products from Japan was the use of the "Japan tube" developed by the New Japan Radio Company. The tube cost less than $25 compared to Raytheon tube which cost $300. Sales grew from 0.1 million in 1971 to 1.6 million in 1976. Although consumer acceptance of Japanese version of the microwave oven was initially low, mainly because of its small size, acceptance grew when the Japanese started introducing larger microwave ovens. The combined sales of Litton and Amana dropped from 67% of the market share to 30% by 1977 in the US consumer market. Various companies such as GE, Whirlpool, Norelco and Sunbeam entered the booming market in 1970s. However, late entrants including Farberware, Admiral Group and Westinghouse left the market writing off substantial losses.

An overview of the business models adopted by pioneers and smart followers in the four cases is provided in table 5. These four cases highlight one major aspect: the pioneers that create a new market and the followers that open up a mass market adopt different strategies. The pioneers often base their product on past experience, and target it at a known niche of high-end customers. With their breakthrough technology they attempt to solve a challenge unsolved by traditional technologies. Often required complementary products and services are either entirely absent or not well developed. Pioneers often have to invest in creating complementary products and services. Followers, in contrast, gain some lead as they built upon the experiences of the pioneers. They have the opportunity to learn from the successes and failures of their predecessor. Besides, the followers have the advantage of using existing complementary products, services, proven technology, consumer awareness and market research.

Table 5: The business models adopted by pioneers and smart followers

Business model→ Technology↓	Pioneer	Smart followers
Photocopier	» Xerox: high end niche market; high speed, high volume, quality prints; *lease* model – low lease rate for machine per month, nominal per copy charge; developed complementary products and services – papers, service parts, dealers, service personnel, financing, etc. » IBM, Kodak: attempted to copy Xerox's business model.	» Canon: mass consumer market; medium speed, medium quality prints, self repairable machine; affordable price; 'razor' and 'razor blade' model – low margin on machine, high margin on cartridges; outsourced servicing, dealership, papers, etc. » Other followers: adopt and adapt Canon's business model.
Video recorder	» Ampex: high end niche market; leveraged on convenience of use and cost effectiveness when compared to predecessor technology; offered a complete package to customers. » Toshiba, RCA, CTI, CSA: targeted a similar niche market, yet dropped efforts mostly due to slow market development and technological complexity.	» Sony, Matsushita and JVC: starting from high-end niche within Japan rapidly switched to household market; built upon the consumer electronics expertise; dramatically reduced the product size; made product affordable; made cassettes widely available.
Digital camera	» Fairchild: built upon its military technology expertise, and contacts with military and space agencies to market CCD chip for digital imaging; targeted premium users such as NASA.	» Sony: targets mass consumer market with still imaging built upon its video recorder. » Fuji, Nikon, Canon and Sony: introduces digital camera based on image sensors; initial poor quality is rapidly improved with the advances in electronics.
Microwave oven	» Raytheon: focus on institutional market with specific needs; robust construction; improves performance step-by-step; offers complementary products and services; high margin; uses cross-licensing to capitalise on patented technology; acquire Amana to introduce simpler product for consumer market » Litton: focused on reliability of product; lowered costs; affordable product for institutional market. » Tappan: introduced smaller-sized, easier to use product, but couldn't survive slow market development.	» Sharp, Panasonic, Sanyo: focused on small size, good-enough heating capacity product for household use; affordable price; dramatically reduced prices based upon the 'Japan tube' costing 1/9th the price of Raytheon's 'magnetron tube'. » US, Whirlpool, Norelco and others: adopted Japanese model. » Farberware, Admiral Group and Westinghouse: couldn't survive a heavily competitive market.

Conclusions

In the article, we focused on whether the actors change during the different phases of the pattern and the strategies the actors adopt.

Actors during the pattern

Depending on the timing of the activity of the actors and on the strategy that they adopt we distinguished four groups: (1) the pioneers; (2) the followers copying the strategy of the pioneers; (3) the smart followers that adopt a different strategy aimed at creating a mass market; (4) the late entrants copying the smart followers. Two findings concerning the actors are worth highlighting. *One*, for all the cases, different actors emerge in each phase. Some actors are only active in the innovation phase, *e.g.* from invention to first market introduction. For example, the Bell labs developed the CCD chip that became a vital component in digital imaging but choose not to become an active player in this market. Some actors appear in multiple phases such as the company Fairchild which remained active in all three phases of the process. *Two*, the number of actors also changes during the technology development process. In all four cases it seems as if the number of actors increases considerably just before products based on the technology start to diffuse in a mass market. This finding is consistent

with that of Agarwal and Bayus (2002) who investigated this phenomenon for thirty cases of major product innovations.

Strategies of pioneers and followers

The pioneers in the four cases first targeted their products at niche markets. Haloid (Xerox), for example, targeted the first photocopiers at the corporate and government market and Ampex targeted the first video recorders at the broadcasters market. In all of the cases these first niches were high-end business markets with a specific need. There are several reasons why pioneers focus on these niches. Firstly, the high-end of the market is willing to pay a premium price. If the pioneer can protect its technology, for example using patents or unique knowledge that is hard to copy, then it makes sense to skim the market, *i.e.* first focus on the niches that are willing to pay most and then gradually lower the price and increase the number of customers. Secondly, when the technology is first introduced, complementary products and services have to be developed. For photocopiers, for instance, ink and paper are required, for video recorders, camera's and tapes are required and so on. In the market adaptation phase the technology and the products are still evolving and so are the complementary products and services because no standards have been set. This means that at first both the products and the complementary products and services are made to measure. This can only be profitable for high-end customers.

Pioneers in none of the cases create a mass market with their breakthrough technology. This statement applies to Xerox (photocopiers), Raytheon (microwave ovens), Fairchild (digital imaging) and Ampex (video recorders). Pioneers seem to stick to the high-end niche markets. They keep developing to improve and serve the needs of their demanding customers. An explanation for this phenomenon is provided by Christensen (1997). Companies tend to upgrade their product and focus on the demands of their current customers rather than make a simpler version of their products and supply it to a broader group of customers. The former strategy is less risky because the wishes of the current customers are well known and they are willing to pay a high price. The latter strategy is more risky because the wishes of the broader group of new customers are not known and the price they are willing to pay is probably much lower. Moreover, supplying the product at a lower price may cause cannibalism of the profitable high-end market.

In our cases we found that followers that just copy the strategy of the pioneer and also focus on these niche markets do not create a mass market. These followers have to find other niches with less potential because the pioneer will have a strong position in the "best" niches. Moreover, these followers often have to pay for licenses to produce and supply their products. Examples of these followers are IBM and Kodak in the case of photocopying. These are strong companies but both decided to leave the market after making large losses. Copying the niche strategy of a pioneer only makes sense in very specific circumstances, for example when patents can be circumvented and when the follower has access to a very profitable niche market that can not be served by the pioneer.

Followers that create a mass market adopt a different approach. The customers in a mass market need a simpler product and are usually more price sensitive than the high-end market. Profitably supplying these markets requires a different business model: a different product design, a different scale of production, a different form of marketing and servicing, and so on. Canon, for example targeted photocopiers on SME's. SME's want simple photocopiers at a low price and are willing to compromise on quality and speed. They also want standard parts and the ability to do most of the servicing of the machine themselves. This strategy entails a more large-scale approach, and this is a viable option when the market uncertainty that prevailed during the market adaptation phase has decreased, *i.e.* when it becomes apparent that more customers want products on the basis of the technology, and when the technology uncertainty has decreased, because standards for the products have emerged and complementary products and services can be supplied by other actors than the pioneer. Therefore smart followers wait and see until the uncertainty has decreased while developing their version of a product, production facilities and service facilities that can be used to create the mass market. In practice, it is difficult to indicate clearly when a market is ready for a mass market approach. This means that the followers that try to create a mass market often have deliberately to probe whether the market is ready for their business model. Canon for example, tried to introduce their photocopiers multiple times before their strategy became a success.

Teece (1997) describes in what circumstances followers rather than pioneers or first movers are most likely to benefit from the (large-scale) commercialisation of the technology. "…when imitation is coupled with design modification before the emergence of a dominant design, followers have a good chance that their modified product will be anointed as the industry standard, often to the great disadvantage of the innovator."(p. 290). Becoming a follower can be a good strategy in these cases but our results indicate that different types of followers can be distinguished: the followers that copy the pioneer and the smart followers that create a mass market. We summarise these findings using figure 3. Figure 3 shows the customers (horizontal axis) that are willing to pay a specific price (vertical axis) for products incorporating a breakthrough technology. Customers in the high-end niches are willing to pay a high price because of the value of the product for them. Then subsequent market niches emerge, each consting of customers that are willing to pay less. The pioneers target their product at the high-end niches, the followers that copy the pioneer target their product at less profitable niches. The followers that attempt to create a mass market are able to drastically lower the price by designing a simpler type of product and adopting a completely different business model. They can make a profit even when the price of the product is much lower, mainly because of the size of the market that they can serve and the simplified product that can be produced, supplied and serviced at lower costs.

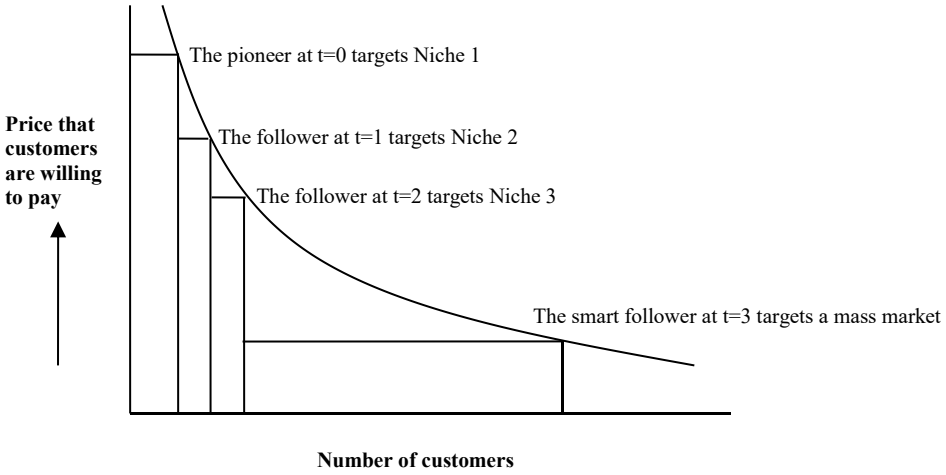

Figure 3. Customer segment targeted by actors

Discussion

Strategies of companies change during the various phases of the product life cycle (PLC) (Swan & Rink, 1982). We added to this line of research by focussing on the technology incorporated in these products and on the phases that precede the PLC. Followers rather than pioneers in some cases benefit from the commercialisation of breakthrough technologies (Teece, 1997; Markides & Geroski, 2005). We add to this line of research by distinguishing different kinds of followers and indicating how their strategies and the chances for success differ.

The results of our cases illustrate that actors enter and leave during the pattern of development and diffusion of breakthrough technologies. In line with the open innovation (Chesbrough, 2003) approach, the actors stop and start their activities at various stages of the pattern. They develop a technology, like the Bell labs did with the CCD chip, and then they can license out this technology rather than introduce a product to the market themselves. Other actors step into the market later by licensing in the technology for production.

Apart from the in our cases other strategies can be adopted to cope with an erratic pattern of development and diffusion. We found that companies rather than just adapting their strategy to the phase of the pattern can also create the pattern. Powerful high-tech companies can afford to wait and see while they keep an option open by buying a share in start-ups, or by venturing activities, and so on. In some cases, these companies can wait and thereby postpone the introduction of a breakthrough technology for years, *i.e.* the innovation phase is prolonged by the strategy of the actor. This additional time can be used to form alliances and set standards prior to market introduction, *i.e.* the market adaptation phase almost disappears because of the strategy of the actor.

A limitation of our research is the number of cases. More cases are needed to refine our findings. More research is also needed to investigate the causes of the market adaptation phase and different types of sub-strategies that can be adopted to cope with this phase. We believe that a number of different causes of the market adaptation phase can be distinguished each of which may require a specific niche strategy. Research is also needed to indicate in what circumstances companies can transform the pattern of development and diffusion.

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