

Technology-Market Matching in High Technology Small Firms

Hanna L. Hellman, Casper Boks

Design for Sustainability program, Delft University of Technology, Landbergstraat 15, 2628 CE Delft,
+31-152782120, h.l.hellman@io.tudelft.nl

Abstract

The commercialisation of a very new technology involves a gradual co-evolution between a developmental technology and emerging markets. The manner in which high technology firms match their technology to market applications has not been described in detail. The firms face critical market application decisions, whilst market demand is difficult to identify and customer desires are not explicitly known. Therefore, this research aims to gain insight into the determinants of market application decisions in high technology small firms. First, this paper reviews literature on strategic decisions and success factors of commercialising new technologies in entrepreneurial firms. Subsequently, the novel and current case of fuel cell technology is examined in an empirical case study of four fuel cell firms. The findings suggest that experience with product and market applications as well as a firm's supply chain position are determinant for the selection of market applications. Further research may contribute to understanding of firm experience as a source of competitive advantage.

1. Introduction

In the early phases of technology commercialisation, high technology firms face uncertain decisions regarding the development and application of their technology. It is difficult to predict which markets will adopt their technology at which point in time. In the case of technologies that are new to the world, markets may not exist as yet. There is a market to apply a technology when a consumer is willing to pay for the technology. Consumer demand exists if there is a willingness to switch spending from the current solution to the new alternative (Howells 1997). Market applications for a technology will emerge as a firm's technology matures. Historic cases have shown, Geels (2000) explains, that a technology is applied in various early adopter markets prior to mass-market acceptance. Scholars have described this process as the co-evolution between a technology and markets. As Martin argues "the process of new market formation involves much more than just getting a technology to work, it requires the formation of completely new social-technical relations" (2001: 63). The co-evolution between a technology and markets has been described at a socio-technical and industry level. However, at a firm level, the manner in which a maturing technology is matched to emerging markets has not been described in detail. How can a high technology firm, that targets the commercialisation of a technology as the key part of its development and marketing strategy, match its technology to markets?

The commercialisation of a new technology involves some kind of coupling or linking between a technology and markets (Balachandra *et.al* 2004, Coombs *et.al.*2001). A technology matches a market, in terms of consumer demand, if the technology performs a task that a consumer desires. Innovation and management literature has shown that success of a new product or technology is strongly related to this match (e.g. Cooper and Kleinschmidt 1986, Utterback 1994). High technology firms are challenged to identify

market applications and consumer demand as well as understand consumer desires whilst markets emerge and their technology matures. Matching a firm's technology to markets involves uncertain decisions on market application, such as, the selection of markets, technology positioning and the timing of market entry. For the high technology firms in an emerging industry, these decisions can be determinant for firm survival and development. This research, therefore, aims to gain insight into the rationale behind their market application decisions.

This research examines the novel and current case Fuel Cell (FC) technology commercialisation. This clean energy conversion technology has the potential to replace combustion engines and batteries in a broad range of products. Over the past ten years numerous FC related firms have been established for the development of fuel cell components, systems and products. This study will examine a selection of these small and entrepreneurial firms. The firms work in an extreme environment of technical challenges as well as a scarcity of available resources. Commercialising their technology, FC firms face challenging market application decision. There are a multiple applications to choose from, whilst it is unclear which markets will accept the technology at which point in time. Additionally, there is high potential for mass market application, but wide spread adoption is preceded by a long pre-commercial period of demonstration, experimentation and learning.

This paper will examine the interplay between high technology firms and their customers in matching a technology to markets. The following questions will be addressed: 1. How is a technology matched to markets at a firm level? 2. What variables influence the match between a firm's technology and market applications? Primarily literature is reviewed to gain insight into the strategic decisions and success factors of technology commercialisation. Subsequently, the methodology and results of the empirical research on small FC firms is described. Finally, based on the theoretical and empirical findings, technology and market matching at firm level is discussed.

2. Literature review

The commercialisation of a technology by high technology small firms draws upon research in multidisciplinary fields. This paper will consider three fields of literature to gain insight into market application decisions and success factors. First, literature on commercialisation strategies, from both a technology and market perspective, will be addressed for an overview of the strategic decisions faced. Second, this paper examines small and entrepreneurial firms and will, therefore, describe literature on the characteristics and success factors of entrepreneurial firms. Finally, characteristic variables of a technological innovation will be described from innovation management literature.

2.1 Technology strategies

A broad scope of literature addresses different aspects of strategic decision making for technology commercialisation. Technology management scholars have described 'technology strategies' in high technology-based firms from the rationale that the management of technology is a determinant of firm survival and performance (e.g. Hamel

and Prahalad 1994, Zahra 1996). A firm's technological strategy implies decisions on which R&D activities to conduct, how and at which point in time. The selection of R&D activities includes decisions on their scope of technology and the degree of R&D investment. A firm may choose to focus its R&D activities to specialise and deepen its proprietary competences, or a firm may choose to conduct a broad scope of R&D activities to secure flexibility and adaptability (Hung *et.al.* 2003). A firm may choose to invest in particular R&D activities or not, depending on its perception of commercial value. Regarding timing, firm's face a strategic choice whether to pursue a leadership role in the development and application of a technology or follow competitor firms in established trajectories. This aspect of entry timing has received extensive attention (e.g. Kalyanaram *et.al.* 1995, Lieberman and Montgomery 1988). 'First mover' advantages of a leading firm are often emphasised, however, scholars have also described follower advantages. Lastly, a firm must decide to develop the technology through internal R&D, through alliances or outsourcing. Advantages and disadvantages of each strategy have been argued in literature. Implications of strategy decisions with regard to the selection of R&D activities can be described through the resource or competence based theory of the firm because the decisions are determinant for the development of a firm's proprietary resources. Besides these issues of technology development, the commercialisation of a new technology involves strategic decisions on marketing and market development.

2.2 *Marketing strategies*

Research on marketing management has described high technology launch and marketing strategies (Shanklin and Ryans 1987, Easingwood and Beard 1989). The rationale behind these studies is that appropriate strategies must be adopted to accelerate rates of adoption to minimise the 'burn-out' risk of pioneers. Strategic decisions include positioning the technology or product in a market through the identification of specific customers and market opportunities. Literature on innovation-market dynamics and the diffusion of innovations show that different customer segments will adopt innovations at different times. Typically, 'innovative adopters' or 'professional heavy users' are early 'niche' markets for a new technology or product. Furthermore, Shanklin and Ryans (1987) explain how the strategic application of a new technology in the market place is characterised by a dominance of supply side marketing. Additionally, firms have to deal with the uncertainties customers have. Strategies to cooperate among competitors in an industry have been suggested to help educate customers and stimulate market demand. A third group of strategies are directed at the adoption behaviour of customers. First, the reduction of the risks that customer's associate with adoption and second, winning market support. Scholars suggest that customers will be more likely to adopt a new technology if the customer can try-out the new technology (e.g. Frambach 1993, Easingwood and Beard 1989). Another approach, although rarely implemented, is for the supplier of a technology to absorb the risk of adoption. Finally, strategies are suggested to win market support by establishing a good reputation.

The above mentioned marketing strategies are, to a certain degree, applicable to both business to business and business to consumer sales, as well as the sales of a product to end-users or a sub-system to original equipment manufacturers (OEM). However, it can

be expected that the sales and supply chain characteristics influence the matching of a technology to markets.

2.3 *Entrepreneurial firms*

What characteristics of an entrepreneurial firm influence firm decisions and firm success? High technology entrepreneurial firms are challenged to grow in an extreme environment of, on the one hand, technological challenges and high investments and on the other hand, a scarcity of available resources and competences. Historical cases have shown that only a small percentage will survive (Olleros 1996). Several studies have identified factors related to the success of an entrepreneurial firm. Kakati (2003) provides an overview of factors covering six areas: entrepreneur quality, resource-based capability, competitive strategy, product characteristics, market characteristics and financial data. Researchers have stressed the role of the entrepreneur, in particular the individual's motivations and qualities, in the success of an entrepreneurial firm. The founders play a critical role in gathering resources and developing strategies to push a product through market. Although the entrepreneur's quality and the firm's origin impact the capabilities and strategy of a firm, Kakati (2003) argues that the resource based- capabilities and competitive strategies of a firm are equally critical. Regarding capabilities, Oakey (2003) additionally recognises that a complex mix of both technical, market and managerial skills are necessary for the success of high tech firms. However, research has also shown that solely having the capability is not a guarantee of success. A commercial understanding through prior experience with customers and markets proves to be critical in the development of a new firm. This prior experience, with customers and applications, is repetitively emphasised as a prominent factor to successfully recognise and exploit market opportunities (Shane 2000, Ardichivili 2003). Nerkar and Roberts (2004) have termed a firm's experience within markets as 'product-market experience'. The relevance of prior experience poses a dilemma for entrepreneurial firms in an emerging industry: they have gained limited product-market experience, yet market applications have to be identified. Several FC firms, for example, are initiating applications and projects with limited experience of their technology in practice.

2.4 *Innovation success*

Innovation management and product development studies have examined numerous success factors for new product development. Here it is repetitively emphasised that a new product should address market needs and that a firm requires an in-depth understanding of customer requirements and demands. However, the difficulty of recognizing customers and their needs, in early phases of technology commercialisation is also recognised (Friar and Balachandra 1999). Certain management practices have shown to be effective for managing this uncertainty, namely, market experimentation or probe and learning (Lynn *et.al.* 1996). Cooper and Kleinschmidt (1986) have additionally shown that prototype testing with customers has a positive impact on the launch of a new product. Jolly (1997) explains that mobilizing interest for, proving the value of and demonstrating a new technology are critical activities in the process of technology commercialisation. The characteristics of an innovation itself are also known to influence the success of a new product. The novelty and complexity of a new technology are

negatively related to the success of a new technology because these characteristics generate uncertainty.

Concluding from the above literature review, the development and marketing of a firm's technology involves several strategic decisions on the development of the technology and markets. Matching a technology to markets at firm level concerns the identification of customer demands and decisions on the selection and timing of market applications. The crux of uncertainty is the difficulty to understand and identify customer demand. Additionally high technology firms have to deal with customers' unfamiliarity with their technology. Innovation and entrepreneurship studies show that the characteristics of both technology and firm are likely to influence a firm's strategic decisions and subsequent performance. Based on the literature review above, it can be expected that entrepreneurial ambition, resources, capabilities and prior experience with market application, will influence a firm's selection of market applications. Additionally, a match between a firm's technology and customers will depend on how a firm manages the novelty and complexity of its technology.

3. Empirical research

3.1 Case study of fuel cell firms

Fuel cells are energy conversion devices that have the potential to replace batteries and combustion engines in a broad range of product applications. However, it is expected that it will be long before a breakthrough into true mass market sales is made. In the mean time FC firms are gradually applying their technology in various niche markets as well as demonstration projects. For FC firms, the challenge of matching FC technology to markets lies in the selection of markets, the identification of customer demand and the timing of applications. In which applications and projects will a FC firm invest its scarce time and financial resources? FC firms show heterogeneous strategies for market application. The firm's match their technology to markets in differently. This research will examine these differences and attempt to explain the motives, drivers and rationale behind the heterogeneous market application decisions.

To understand how technology and market matching takes place within FC firms, this research requires an in-depth look at FC firms. A case study research strategy is utilised to examine a select number of fuel cell firms. As Yin (1994) explains, case study research is suitable to study real world situations and particularly suited to identify multiple factors that influence the phenomenon under study. The case study research is primarily conducted through open interviews with fuel cell firms. Besides, firm data is collected on the resources and activities of each firm, including patents, press releases and financial data.

3.2 Case selection and description

Four case firms have been selected based on a maximum difference of market application strategy. Two market application decisions are taken as dependent variables in order to examine the factors that have determined these decisions. These dependent variables are, the way market applications are selected, and the time horizon on which the first market

application is expected to become commercial. Figure 1 shows how both dependent variables were used to motivate the choice of four case study firms.

Regarding the selection of market applications, firms can choose to focus on a narrow and specific technology application trajectory or choose to compete on a broader field of applications. This decision is related to how a firm allocates its resources. The degree of market focus is defined as the number of markets to which a firm's resources are allocated. Firm A's focused selection implies the focused allocation of resources to specialise on particular markets. Expected consequences are a strong position as leader in this market, with unique and specialised competences, yet a risky reliance on the success of these markets. Firm D, on the other hand, invests time in numerous markets. The firm is not selective of applications. Although this approach enables flexibility and gives access to subsidised support, the firm may not develop unique competences and risk wasting resources on 'dead end roads'.

		Market selection	
		Focused	Broad
Time to first commercialisation	Immanent	Firm A	Firm B
	Near	Firm C	Firm D

Figure 1: Choice of case study firms based on two dependent variables.

The second variable concerns the content and timing of the first market application decision.

It is related to the challenge of managing the long FC pre-commercialisation period. The decision is relevant because it says something about which firm will access a profitable market first. Firm A and Firm B have chosen for the same early adopter market: back-up power. The profitability of this application is calculable and the firms have received repeat orders from customers. The commercialisation of this application is, therefore, immanent. Firm C and Firm D have chosen for applications, a motorbike and a power plant respectively, with near-term potential. The technical as well as the economic feasibility of these applications still have to be proven.

Each case firm conducts similar FC development activities. The firms are small and have all been founded 5 to 10 years ago. Table 1 illustrates the firm characteristics. Firm A is focused on the development of fuel cell systems for onsite energy generation. The company develops and delivers end-products to end-users. It is currently targeting specific business to business markets for its back-up power products. Firm B targets early adopter markets for back up power as well as particular markets for fork lift trucks. The company supplies fuel cell modules, comprising of complete fuel cell systems to Original Equipment Manufacturers (OEMs). Firm C does not select particular market applications. However, the company has developed a fuel cell motorbike for demonstration and is now further developing this product. Firm D is focused on the development of fuel cell stacks, the main component of a FC system, than on the market application of its technology. The company targets the supply fuel cell stacks and conducts projects in a broad diversity of market applications.

Table 1: Characteristics of firms in the case studies

Characteristics	Firm A	Firm B	Firm C	Firm D
Firm size	330	325	70	25-30
Year of founding	1997	1995	2001	1998
Competence at founding	FC technology	FC test systems	FC technology	Materials, Akzo
Core FC business	FCs for onsite energy	Module production	R&D	FC Stack production
FC supply	Back up and prime power	FC modules, stacks	License agreements	FC Stacks
FC Markets	Onsite power generation	Mobility, portable, stationary	CHP, aircrafts, remote power, automotive,	Portable, stationary and automotive
Targeted near-term market(s)	Telecom and cable back up, prime power remote locations,	Back-up power and fork lift trucks, portable power army	Premium consumer market	PEM power plant Fork lift
Demonstration	Home Energy system	Technology demonstrators mobility	ENV motorcycle	Buses, CHP
Power range	5kW	500W-65 kW	50W-75kW	500-20kW (stackable)
Other H Technology	Onsite H ₂ generation	FC test stations, onsite H ₂ generation,	Reforming, H ₂ generation, storage	Reforming

4. Results empirical research

The empirical research results are presented in four sections. Primarily, paragraph 4.1 provides an overview of how the fuel cell firms match their technology to markets. This section describes the considerations for a ‘good match’. Subsequently, differences and similarities between the case firms are described in three sections. First, the motivation and drivers for market selection are addressed and secondly, the observed determinants for the selection of markets are described. Lastly, quantitative findings supplement the qualitative results.

4.1 Match considerations

How does a FC firm match its technology to markets and in particular to customer demand? The interviews addressed the considerations and criteria for a good match. Each firm explained how a first evaluation of an application can be made to roughly determine its technical and economic feasibility. The price and performance of incumbent technologies in a particular market are used to benchmark and evaluate an application. This is a fundamental, and at least partly calculable, comparison of FC technology with the current alternatives. Subsequently it is not surprising that the case firms recognise the potential for fuel cells in similar markets and approximate a similar adoption order. The early markets for back-up power, fork lift trucks and later markets for heat and power appliances and mobility markets are well-known and eagerly discussed.

However, FC firms are uncertain when and which specific markets and market segments will adopt their technology. Firm A has done market research and determined its market focus through extensive conversations with potential customers. As Firm A states, “...at each client, whenever we talk about back-up [power]... we gain more knowledge ... we also learn quickly which parts of those 6000 sites are economically profitable”. Firm B explains that “...it is difficult to know who really wants it”. This company states that it has to do demonstration projects in a particular market in order to understand which

specific market and operational demands to target. The firms are looking for and learning about which specific markets match the performance of their current technology. This match requires an understanding of specific customer demands and the technology's operational performance.

In order to predict how a firm's technology will perform in operation, the firms have to gain practical experience and generate operational data. Firm A has generated a database of operational information from extensive field test experience. Firm D is conducting its first field tests: "...what it now really comes down to are field tests ... you are really confronted with all kinds of things, because it is for the first time, it is new, it is different". As Firm B explains: "...you have to do a demo first to know the real costs, the unexpected costs etc...". To match the technology to a customer's demands, the firms need to gain experience with operation in practice. Without operational information, Firm B explains, "... OEMs have too many questions that can not be answered with authority". Thus, matching at firm level additionally requires validation and proofing of a technology, on the one hand, to know which customer requirements the firm can and cannot meet, and on the other hand, to answer a customer's questions and doubts.

The FC firms acknowledge that customer's are, more often than not, unfamiliar with fuel cell technology. As a consequence the firms have to educate customers and explain the technology. As Firm C states "... the frustrating thing is going out to customers and having to explain the technology". Firm C has chosen to develop a 'beautiful' product in order to explain its technology: "... the beauty was a way of opening the doors so that people could understand the technology". Firm A's back-up power product cannot be prized through its beauty. The firm spends a lot of time to generate awareness among potential customers. Firm A also explains that "... you have to explain them just about everything about fuel cells". It is, however a balancing act to enthuse customers without generating too high expectations. Firm D, aims to supply FC stacks, but is confronted with OEM customers that do not have the capability to develop and integrate a fuel cell system as yet. For that reason firm D has chosen to "... help system integrators on their way... ", by delivering or jointly developing a FC system. This last observation shows that a FC firm has to match the way it supplies its technology to the capabilities of a customer.

Finally, FC firms match their technology to markets at the level of customer requirements. The FC firms further design and specify their technology as customer requirements gradually become more concrete and clear. The FC firms manage this process in different ways. Firm B supplies a fuel cell module to customers, who provide feedback for module modifications or improvements. These OEM customers experiment with the integration of the module in their products. Currently, Firm D jointly specifies and develops a system with a customer OEM. By contrast, Firm A is responsible for an end-product that will not be introduced until the operational tests prove that customer requirements can be met. Similarly firm C explains that regarding the development of its motorbike, "... there are high expectations and we either have to satisfy them and launch or if we consider we can't satisfy we won't launch". The supply chain position of the firm, therefore, determines how a customer's requirements should be matched to the

technology. The match considerations described above suggest that a firm’s level of product-market experience and a firm’s supply chain position influence the process of finding a match.

4.1 *Motives and drives*

In matching their technology to markets, FC firms have made heterogeneous selection decisions. What are the motives behind the different market application decisions? The interviews reveal heterogeneous motives and drives (see Table 2). Firm A and B’s motivation for the development of fuel cell technology is driven by the perception of market demand. Firms B and C were founded with the motivation to develop fuel cell technology, driven by the perceived potential of the technology. These firms prioritise the development of hydrogen and fuel cell technology above the development of applications for their technology. By contrast, Firm A is highly focused on a near-term commercial roll out, motivated by the perception of market demand. Firm B targets a similar early adopter market based on perceived market demand, but is also driven by the possibility to achieve production volumes to validate the development of a production facility. Firm C is targeting the near-term development of the motorbike quite unexpectedly. The firm is motivated by immense consumer feedback to an earlier demonstration. “We cannot ignore the consumer” firm C explains. Firm D is developing a FC power plant, motivated to gain practical experience, achieve volumes and validate the technology.

Each firm is engaging in niche market applications. Firm A and B target commercially viable first markets in order to become profitable as soon as possible. Firm C and D appear to engage in niche market applications as a manner to bridge the period to mass market acceptance. The motivation to conduct and select demonstration projects is diverse. Firm A has conducted demonstration projects with launching customers in order to prove the technology and convince the targeted market. Firm D’s motivation is also validation, but of their technology in general and to gain operational data. Firm B’s technology demonstrator strategy is motivated by the need to learn about “who really wants it”. Additionally, this strategy is used to validate and demonstrate their technology to a broad scope of potential OEM markets. Firm C’s demonstration project targets the broadest audience: “... I think that it was done because we needed a way of demonstrating to a wider public, that this technology was ready to rumble”. The demonstration is used to enthuse a broad public and as a tool to explain the technology. Firm C has chosen a complex product, to demonstrate their technical capability. The motivation for focused or

Motivation	Firm A	Firm B	Firm C	Firm D
FC technology	Market driven	Market driven	Technology driven	Technology driven
Near-term application	Perceived market demand	Perceived market demand and volumes	Consumer feedback/ demand	Learning and volumes
Niche markets	Commercial market	Commercial markets	Fill gap	‘necessary evil’
Demonstration project	Prove and convince	Learning, validate, small market	Enthuse and explain	Learn, validate, resources
Product development	Low product integration complexity	Can not develop all those products	Show what can be done	Leave to system integrators

broad market selection and first markets appear to be related a firm's product-market experience with identifying customers. Additionally, the degree of learning appears to be related to a firm's supply chain position.

4.3 Decision determinants

What firm characteristics influence a firm's market application decisions? The similarities and differences between the case firms are summarised in table 3. First, differences in the firms' application objectives were observed. Second, the interviews have shown variable levels of product-market experience. Finally, differences and similarities of firm resources were noted.

A difference has been observed in the degree to which a firm is concerned with the development of an application. Will the firm invest resources in the development of a product? This depends on the supply chain position of the firm and its historic ambition. Firm A supplies an end-product and has targeted on-site energy applications at founding. The other firms did not target any particular market applications at founding and aim to supply their technology to OEM customers. Firm C is an exception in that the firm is now committed to the development of the motorbike whilst it is structured as an R&D firm.

The case firms show a variable level of experience with the application of their technology. This variance appears to influence market application decisions. Several types of product-market experience were observed: field test experience, experience in demonstration projects, access to market information, experience with customer feedback and demand. A field test is a test of the performance of a new product under the conditions in which it will be used. The case firms all acknowledge that data on operational performance is essential in order to prove the technology to customer. Firm A has conducted extensive field tests with customers and generated a database of operational data for their back up power products. By contrast, Firm D is developing its first field test applications to gain practical experience and validate their technology in operation. Firm B is gaining field test experience in projects with OEM clients that actually overlap field tests and demonstration.

Demonstration projects involve the implementation of the new technology such that various stakeholders can evaluate and assess the value and merits of widespread application. Demonstration projects provide FC firms with valuable product-market experience. Firm A has conducted several demonstration projects with launching customers. Firm B has applied its module in numerous and diverse demonstration projects with customers. Firm C has gained extensive consumer feedback from its motorbike demonstration project. Besides, a group of supporters for this motorbike has formed in response to the demonstration. They provide a unique consumer base for market research.

Market research provides product-market experience to better understand customer needs and requirements. Firm A has conducted market research, in the form of conversations with clients, to determine its market focus. These conversations with clients are used, on the one hand, as criteria to test and develop their products and, on the other hand, to

specify in which specific applications their product is profitable. Firm A and B have received repeat orders for back-up power products. This explains why they have selected similar early adopter markets.

The resources of each firm, in terms of financial assets and capabilities, are variable. An obvious difference is the financial structure of the firms. Firm A and Firm B are publicly listed firms. Both explain that the financial market pressures the firms to become profitable as soon as possible. Firm C and Firm D depend on private investors and have fewer resources to spend. Regarding capabilities, the firms show similar capabilities for fuel cell stack design. Firm A differentiates itself with manufacturing capabilities, Firm B with its unique module / system design, Firm C with its innovative stack and system design, and finally Firm D with its stack expertise. Regarding market application capability, it is notable that Firm A and Firm D have hired an expert in the targeted market to bring their product to market.

	Firm A	Firm B	Firm C	Firm D
Objective				
Supply chain position	Products to B2B	Modules to OEMs	R&D, IP licensing	Stacks to OEMs
Application objective	End product	Arms length	Arms length	Arms length
Historic ambition	Profitable FC products	Hydrogen products	Licensing of H ₂ technologies	Stack production
Experience				
Field test	Extensive, data base of 2 products	Validating through tech. demonstrators	Several projects for customer	Initial application, validation
Demonstration	3 projects with launching customers	Module applied in numerous projects	Motorbike project	Initial projects, Feasibility studies
Source of market Information	Conversations with clients	Demonstration projects	Motorbike supporters	Clients that approach the company
Customer feedback	Repeat orders	Repeat orders	Reaction to motorbike	
Resources				
Financial	Public	Public	Private	Private
Capabilities	FC, manufacturing	FC, module	FC, stack	FC stack R&D

4.4 Demonstration experience

The interview findings suggest a variable level of product-market experience and resources. Data has been sought to support this observation. Demonstration experience has been quantified by the number of operational demonstration projects a firm has completed. This data has been collected from press releases. Resources, in terms of intellectual property, have been quantified by the number of patents a firm has. This data has been collected from the European database office¹.

The number of demonstration projects completed over the previous eight years by each firm is shown in figure 2. Firm A and B have started with operational demonstration projects years before firm C and D. Additionally, firm A and B have completed significantly more projects than firm C and D. The graphs suggest that Firm A and B have gained significantly more demonstration experience than firm C and D.

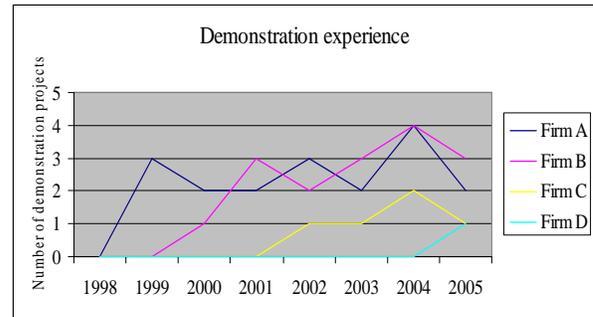


Figure 2: Demo projects completed in each year

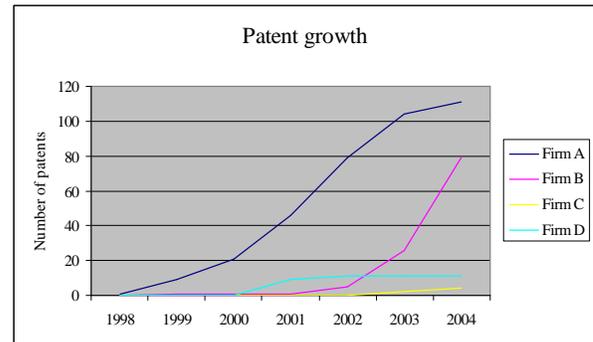


Figure 3: Total number of patents in each year

The total number of patents acquired over the previous eight years shows a large difference between firms A and B and firms C and D (Figure 3). Firm A shows a steady growth of patents as of 1998. As for firm B, the number of patents shows a steady growth since 2002. This period coincides with the development of Firm B's module that has been applied a numerous technology demonstration projects.

5. Discussion

In the following paragraph the interview and literature findings are discussed to understand 1. how a firm matches its technology to markets and customers and 2. the variables that influence the match between a firm's technology and its customers.

5.1 Matching

The literature review (paragraph 2) suggests that matching a technology to market involves an evaluation of a technology's functions and performance with respect to consumer needs and requirements. In practice, the interviews demonstrate that a rational comparison between a technology's value proposition and the current alternatives provide a good indication of interesting markets. However, the FC firms show that it is challenging to determine which specific market segments and customers to target. As innovation studies suggest, FC firms do not have a clear understanding of customer

¹ <http://www.european-patent-office.org>

needs. Besides, FC firms show that the performance of their technology in operation may not be explicitly known. Two FC firms conduct demonstration projects to learn and ‘look for’ a match between the operation of their technology and the operations to target. Two FC firms learn which applications are profitable through conversations with possible customers. It is challenging to identify the customers that are willing to pay for the current operational performance of the technology.

A second consideration (figure 4) to apply a technology in markets involves communication and education with respect to a customer’s understanding and expectations. The literature review suggested that a customer’s unfamiliarity with a technology generates uncertainty and

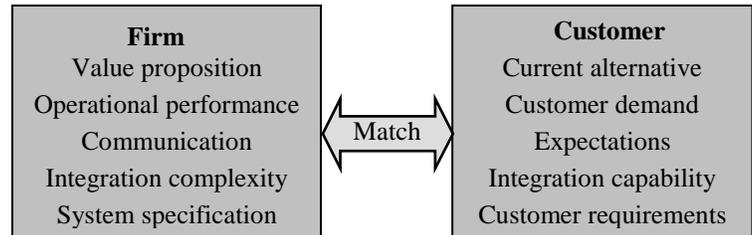


Figure 4: Considerations to match a firm’s technology to customers

influences market adoption. Strategies may be applied to reduce this perceived risk of adoption. The interviews show that FC firms educate customers to create awareness and enthusiasm. The firms supplying end-products are challenged to carefully manage customer expectations. The FC firms that supply systems to OEMs educate their customers on product integration. Firm B has developed a near ‘plug and play solution’ and Firm D provides system integration services. As the literature review suggests, reducing the perceived complexity and uncertainty of a technology, will increase the rate of adoption. A third consideration is, therefore, to match the technology supplied with the product integration capabilities of the customer OEM. The last consideration of matching a technology to markets at firm level involves design and development. Product development literature states that a system or product should be designed to meet customer’s requirements. The FC firms design systems and products according to customer requirements and customer feedback is used to further optimise the fit with customer requirements. In the case of end-products, design is targeted to compete with the current alternatives. In the case of OEM customers, systems are often developed jointly. Matching a firm’s technology to customer requirements is a gradual process of alignment.

5.2 Matching variables

The literature review in paragraph 2 describes strategic decisions and several variables related to the success of a new technology and a high technology firm. Entrepreneurial ambition, resources, capabilities and prior experience are expected to influence strategic decisions and their success. The interviews with fuel cell firms reveal motives for the selection of market applications including internal learning and external communication. A firm’s application experience and its supply chain position appear to be determinant for the selection of market applications.

FC firms that supply a FC system to OEM customers, responsible for product integration, select a broad scope of applications to engage in. Strong motivations are, 1.to learn which customers to target and, 2.to show potential customers that their system can be applied in

many different products. FC firms that supply end-products to customers have focused on select market applications. Their resources are focused on bringing their product to a specific market. These FC firms are motivated by a strong perception of customer demand. Regarding the second dependent variable, there are two firms that have recognised a commercial early market. These firms appear to be ‘market driven’ as they develop FC technology and applications in reaction to a perception of market demand. Additionally, these firms appear to have gained more product market experience and resources than the other two firms. These observations suggest a difference in phase of development. As scholars suggest, small high technology firms must evolve from a technology drive to a market led management (Balachandra *e.al.* 2003, Berry 1996, Kakati 2003).

Matching at firm level depends on the technology that particular firm supplies and the respective customer’s familiarity with the technology. To identify customer demand and understand customer requirements a firm needs product-market experience (Figure 3). The required level and type of product-market experience appears to depend on a firm’s supply chain position. For the supply of a system there are many possible OEM customers. Additionally, operational performance of the technology is uncertain until applied in an OEM’s product. Besides, an OEM customer may be uncertain about its capability to integrate the system into its products. By contrast, for the supply of a product, the scope of potential customers is already limited. The product can be optimised according to the requirements of the targeted customer group, prior to introduction. Thus, a firm requires more product- market experience, through collaboration with customers, to match its technology to OEM customers. The required level of application experience additionally depends on the familiarity and capabilities of a customer.

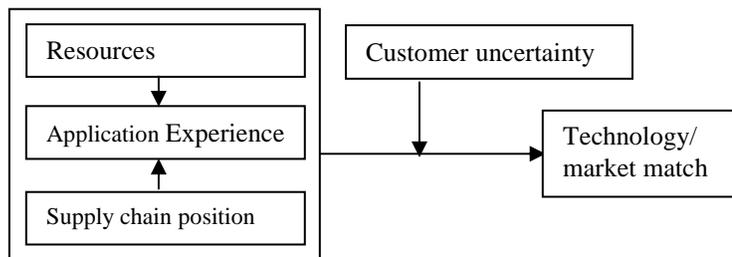


Figure 3: Determinant factors of a high technology firm for matching a technology to markets.

Concluding, there appears to be a relation between a firm’s product-market experience and its ability to recognize profitable markets and customer demand. Scholars have argued that a firm’s assets often develop as a function of its different experiences (Barnett and Hansen 1996, Ingram and Baum 1997). In line with the resource based theory of the firm, this paper, therefore, suggests that product-market experience is a source of competitive advantage. This paper presents preliminary findings. Further research will examine this relation through a second round of interviews. Besides, the research requires more data of the case firms, such as such as patents and financials, to argument the findings.

6. Literature

- Balachandra, R. Goldshmitt M. Friar, J.H. (2004). The evolution of technology generations and associated markets: a double helix model. *IEEE transactions on Engineering Management*. 51 (1) p.3-10.
- Barnett WP, Hansen MT. (1996). The red queen in organizational evolution. *Strategic management journal*, summer special issue. 17, 139-157.
- Berry MMJ. (1996) Technical entrepreneurship, strategic awareness and corporate transformation in small high-tech firms. *Technovation*. 16 (9) 487-498.
- Cooper RG, Kleinschmidt EJ. (1986). An investigation into the new product process: steps, deficiencies and impact. *Journal of Product Innovation Management* 71-85.
- Coombs RK, Green A, Richards & Waksg V (eds.) (2001) *Technology and the market: demand, Users and innovation*. Edward Elgar, Cheltenham, UK.
- Easingwood C, Beard C. (1989). High technology launch strategies in the U.K. *Industrial marketing management* 18, 125-138.
- Frambach RT. (1993). An integrated model of organizational adoption and diffusion of innovations. *European Journal of Marketing*. 27 (5) 22-41.
- Friar JH, Balachandra R. (1999). Spotting the customers for emerging technologies. *The J. of Product Innovation Management*. July-august; 37-43.
- Geels, F. (2002). Understanding the dynamics of technological transitions. A co-evolutionary and socio-technical analysis. Dissertation University Twente.
- Hamel G, Prahalad CK. (1994) *Competing for the future*. Cambridge MA. Harvard business school press.
- Howells J. (1997). Rethinking the market-technology relationship for innovation. *Research Policy*. 25, 1029-1219.
- Hung SC, Liu NC, Chang, JB. (2003) The taxonomy and evolution of technology strategies: as study of taiwan's high technology based firms. *IEEE transactions on Engineering Management*. 50 (2) 219-227.
- Ingram P, Baum JAC. (1997) Opportunity and constraint: organizations' learning from the operating and competitive experience of industries. *Strategic management journal*, summer special issue. 18, 75-98.
- Jolly VK. *Commercializing new technologies, getting from mind to market*. Boston: Harvard business school press 1997.
- Kakati (2003) Success criteria in high-tech new ventures. *Technovation*. V.23. p.447-457.
- Kalyanaram GK, Robinson WT, Urban G. (1995) Order of market entry: established empirical generalizations, emerging empirical generalizations and future research. *Marketing science*. 14 (3) 212-221.
- Lieberman MB, Montgomery DB. (1988). First-mover advantages. *Strategic Management Journal*. 9, 41-58
- Lyn G.S, Morone J.G, Paulson A.S. Marketing and discontinuous innovation: the probe and learn process. *California management review* 1996; 38 (3): 8-37.
- Martin B. (2001). Great expectations: The construction of markets, products and user needs during the early development of gene theory in the USA. In R. Coombs *et.al.* 2001.
- Oakey R. (2003) Technical entrepreneurship in high technology small firms: some observations on the implications for management. *Technovation*. 23 (8), 679-688.
- Olleross FJ. Emerging industries and the burnout of pioneers. *J of Product Innovation Management* 1996; 1: 5-18.
- Shanklin WL. Ryans Jr, JK. (1987) *Essentials of marketing high technology*. Lexington books, Toronto.
- Utterback, JM. (1994). *Mastering the dynamics of innovation*. Harvard business school press, Boston, MA.
- Yin RK. (1994). *Case study research design and methods* (2nd ed.). Sage Publications.
- Zahra SA. (1996) Technology strategy and financial performance: examining the moderating role of the firm's competitive environment. *Journal of Business Venture*. 11 (3) 189-219.