The role of market and technological knowledge in recognizing entrepreneurial opportunities

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Abstract

Purpose – Opportunity recognition is an important aspect on entrepreneurship, especially for technology-based ventures. Drawing on Austrian economic theory, recent studies have emphasized the importance of market knowledge in opportunity recognition. Although insightful, these studies do not take account of relationships that exist between different types of knowledge (e.g. technology and market knowledge). The authors aim to address this gap by integrating the Schumpeterian theory of opportunity development with Kirzner's theory of opportunity discovery to examine these relationships.

Design/methodology/approach – The data consist of a longitudinal sample of 42 new biotechnology ventures from the USA, Finland, and Sweden.

Findings – The paper finds that both market knowledge and technological knowledge (measured as the number of patents) contribute to firms' subsequent recognition of entrepreneurial opportunities.

Originality/value – The results show the value and importance of early market knowledge and technological knowledge for subsequent opportunity recognition. The empirical findings are reflected in the light of current research on Kirznerian and Schumpeterian opportunity recognition.

Keywords Entrepreneurship, Opportunity recognition, Biotechnology, Austrian economics, Knowledge organizations, Knowledge management

Paper type Research paper

1. Introduction

The recognition of entrepreneurial opportunities is a necessary step on the path to commercializing science and technologies (Siegel *et al.*, 2003, 2004). Drawing on Austrian economic theory, researchers have identified idiosyncratic knowledge as a key driver of entrepreneurial opportunity recognition (Hayek, 1945; Kirzner, 1979; Shane, 2000). However, the mechanisms through which knowledge contributes to entrepreneurial opportunity recognition are still unclear. There are only a few empirical studies of these theories (Teach *et al.*, 1989; Singh, 2000; Choi and Shepherd, 2004; Saemundsson and Dahlstrand, 2005), given the difficulties in defining and measuring both knowledge and entrepreneurial opportunities. Most studies of the role of knowledge in entrepreneurial opportunity recognition have been qualitative (Shane, 2000; McKelvie and Wiklund, 2004; Park, 2005; Sanz-Velasco, 2006). Our paper contributes to the field of entrepreneurial opportunity recognition through a

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comprehensive assessment of two types of knowledge – new technological knowledge and market knowledge – behind entrepreneurial opportunities recognized in the field of modern biotechnology.

Entrepreneurship researchers, following in the Austrian economics tradition, essentially argue for a positive linear relationship between the amount of knowledge the individual has and the amount of entrepreneurial opportunities recognized by the individual, given the same level of alertness (Gaglio and Katz, 2001; Ardichvili *et al.*, 2003; Holcombe, 2003; Lumpkin and Lichtenstein, 2005; Park, 2005; Ozgen and Baron, 2007). However, elsewhere in the literature researchers have demonstrated that there are interrelationships between different types of knowledge; possessing one kind of knowledge may blindside an entrepreneur or a firm to another type of knowledge. These interrelationships have best been demonstrated as tradeoffs between technology knowledge and market knowledge (Hamel and Prahalad, 1991; Leonard-Barton, 1995; Christensen, 1997; O'Connor, 1998).

The purpose of this research is to understand the role of market knowledge in entrepreneurial opportunity recognition in technology intensive firms. Based on this research, we will have a better understanding of the role of idiosyncratic market knowledge and new scientific knowledge in the recognition of technology based entrepreneurial opportunities.

Following the literature review presented in this paper, specific hypotheses are developed regarding the role of market knowledge in entrepreneurial opportunity recognition. There are two different mechanisms through which market knowledge influences entrepreneurial opportunity recognition. The mechanisms suggested are:

(1) The positive moderating role of market knowledge in the relationship between technology knowledge and entrepreneurial opportunities recognized in a young high technology venture.

(2) The direct positive effect of market knowledge on the entrepreneurial opportunities recognized in a young venture.

The hypotheses are tested in a dataset from young biotechnology ventures.

Roughly speaking, biotechnology is defined as the application of knowledge of living organisms and their components to industrial products and processes (Brink *et al.*, 2004). Out of the different technology categories underneath the biotechnology "umbrella", this study focuses on pharmaceuticals, diagnostics, medicine and the application of biomaterials for medical purposes.

Modern biotechnology is a field characterized by dynamism and rapid obsolescence of scientific and technological information. Idiosyncratic knowledge among players in the field of biotechnology should result in plentiful entrepreneurial opportunities, if we follow the Austrian logic (Hayek, 1945; Kirzner, 1973, 1997; Shane, 2003). Two characteristics are typical of biotechnology products in the categories specified previously. First, at the launching of a project, the product still requires a functional definition. This means that the idea has been identified, the patent has most likely been filed, but the business opportunity is still unclear. Second, the development requires a program of scientific research of the main phenomena associated with the product. This development, including the typical preclinical and clinical test phases, is highly regulated by authorities such as the Food and Drug Administration (FDA). Hence, the "components" of the opportunity discovery and development process are given; if the idea is to be developed into a commercial product, it should be patented and has to go through certain phases of testing and development. A wealth of the research that has tried to encapsulate the peculiarities of entrepreneurial opportunity recognition has focused on identifying various motivations of or stages in the opportunity recognition process (Teach *et al.*, 1989; Bhave, 1994; Krueger *et al.*, 2000; Gaglio and Katz, 2001; Lumpkin and Lichtenstein, 2005; Park, 2005; Mitchell *et al.*, 2007). If entrepreneurial opportunities are a function of the characteristics of an entrepreneur, a new venture idea, and environmental variables as suggested by Singh (2000), then holding factors in the "environment" constant makes it easier to study the role of the entrepreneur as well as the venture idea. By focusing on entrepreneurial opportunities in biotechnology, the main components of the opportunity recognition environment are given. Hence, instead of trying to draw generalizations on the components of opportunity recognition and development process – a task that has proven to be a challenging and controversial one, not least because of the great variations in the ways that individuals come up with business opportunities – we can truly focus on the role of market knowledge in entrepreneurial opportunity recognition.

Even though individuals initially discover opportunities, they are typically developed in firms. Recognizing an entrepreneurial opportunity is perceiving a possibility to introduce innovative (rather than imitative) goods or services to a marketplace through:

- the founding and formation of a new venture; or
- the significant improvement of an existing venture (Gaglio, 2004; Singh, 2000).

Because recognition only entails perception, it follows that exploitation of an opportunity is a separate activity. The exploitation of an opportunity refers to those activities committed to:

- the founding and formation of a new venture; or
- the significant improvement of an existing venture in order to introduce innovative (rather than imitative) goods or services to marketplace.

Because undiscovered opportunities are impossible to identify for research purposes, it follows that the level of analysis in the current study is a firm (Companys and McMullen, 2007; Lumpkin and Lichtenstein, 2005; Park, 2005). Opportunity recognition is a process and that it can occur both prior to firm founding and after firm founding throughout the life of the firm (Singh, 2000).

2. Literature review and theory development

2.1 How are entrepreneurial opportunities recognized?

Even if there is no consensus in the research community over what exactly constitutes entrepreneurial opportunities, it would be hard to find a scholar in economics or management who would challenge the argument that entrepreneurial opportunities are important (McMullen *et al.*, 2007). Given the importance of opportunities, the next big questions are who, how and when recognizes those opportunities? As expected, there are only ambiguous answers to these questions. For one, the philosophical nature of the opportunity itself (over which there is obviously no agreement in the research community) has implications on how that very opportunity is recognized (Ardichvili *et al.*, 2003; Sarasvathy *et al.*, 2003; Alvarez and Barney, 2007). Second, even if we decide on the nature of the opportunity, establishing boundaries around whatever constitutes "recognition" is still challenging. Is recognition limited to the kind of "Eureka" experience described, for example, in Gaglio's work? Or is opportunity recognition a process that spans over time, as many would suggest (Fiet, 2002; Shane, 2003; Park, 2005)? And how active or passive is the role of an alert entrepreneur in the process that brings opportunities from the philosophical world of ideas to the everyday world of business?

Essentially, entrepreneurial opportunities can be recognized based on a technological innovation (Schumpeter, 1934; Drucker, 1985), in which case the supply of technology is known and market demand is unknown (Sarasvathy *et al.*, 2003), or they can be recognized because different market participants have unequal access to information about the market conditions (customers, markets, and ways to serve markets) (Kirzner, 1973, 1997; Shane, 2000, 2003), in which case the demand in the market is known to some, but the supply has to be developed.

In general, two approaches to the study of entrepreneurial opportunity recognition can be identified in existing literature. First, there are those researchers that have studied the "black box" of opportunity recognition. Most of these studies have adopted a cognitive approach in order to understand "How do entrepreneurs think, reason, and behave such that they create value and wealth through the identification and implementation of market opportunities?" (Mitchell *et al.*, 2007, p. 5). Still, other researchers have tried to divide the "black box" of entrepreneurial opportunity recognition into components that describe the overall process. Second, and more relevant to the research question of this paper, there are those studies that have, instead of cognitive aspects, focused on the inputs that go to the opportunity recognition process. The rest of the literature review that follows is devoted to describing research on the sources of entrepreneurial opportunities, that is, the knowledge inputs that go into the opportunity recognition process.

2.2 Knowledge and opportunity recognition

A common theme in much research on opportunity recognition has been the suggestion that information plays a crucial role in the OpR process. At extremes, opportunities that stem from predominantly technological knowledge (science push) versus those that are based on idiosyncratic information about customers, markets, and ways to serve markets (market pull) have very different characteristics. In line with Shane (2003), we call the "science push" opportunities Schumpeterian and the "market pull" opportunities Kirznerian[1].

Essentially, Kirzner (1973) and Schumpeter (1934) disagreed over whether the existence of entrepreneurial opportunities involves the introduction of new information or just differential access to existing information (Shane, 2003). Kirzner's (1973, 1997) view is that the existence of opportunities only requires differential access to existing information. People use the idiosyncratic information that they have to form beliefs about the efficient use of resources – owned or controlled. Because people's decision making frameworks are not always accurate, they make errors (Gaglio and Katz, 2001), which, in turn, create opportunities for others to access and recombine resources in a way that creates entrepreneurial rents (Alvarez and Barney, 2004; Alvarez and Busenitz, 2001). Schumpeter's (1934) contrasting view is that new information is important in explaining the existence of entrepreneurial opportunities. Changes in technology, political forces, regulation, macro-economic factors and social trends create new information that entrepreneurs use to recombine resources in a more productive manner. In technology intensive markets, especially the changes in existing technology base can result in the kind of new information that, in Schumpeter's view, leads to entrepreneurial opportunity recognition.

A clear-cut distinction between opportunities that are based on new versus existing information is, in reality, hard to establish. In a review of Shane's interpretation of Schumpeterian and Kirznerian opportunities, Buenstorf (2007) arrives at a conclusion that all opportunities must be created by new knowledge. However, given the different types of knowledge – new vs existing, technology – vs market related – identified in the literature, it is surprising that existing empirical contributions to OpR literature typically disregard these different types of knowledge and their combined effects on OpR. In the following, the separate and combined effects of new technology knowledge and idiosyncratic market knowledge on subsequent OpR are discussed.

2.2.1 Technology knowledge. Schumpeter (1934) does not explicitly feature the opportunity concept. Instead, his point of departure is the notion of innovation characterized as a new combination. The entrepreneur is an individual who creates a new combination and pursues it in the market. This happens possibly – but not necessarily – through forming a new firm (Dutta and Crossan, 2005; Buenstorf, 2007). Schumpeter's new combinations (opportunities) are discontinuous by nature, and the central message in Schumpeter's writings about entrepreneurship concerns the concept of novelty. Schumpeter repeatedly pointed that while ordinary economic behavior is more or less automatic in nature, the entrepreneur always has to think very carefully about what action to take since she is involved in doing something that is fundamentally new (Swedberg, 2000; Dutta and Crossan, 2005). This emphasis on novelty applies to the information that is the basis of an entrepreneurial opportunity. Schumpeter's entrepreneurs utilize novel information on, for example, technology and science to figure out how to recombine resources in a more productive way (Shane, 2003). Schumpeter's approach differs from the Kirznerian tradition in that opportunities are not pre-supposed for entrepreneurial activity to occur, but are created by the innovative entrepreneur herself (Sarasvathy *et al.*, 2003; Buenstorf, 2007).

Shane (2003) lists some empirical evidence that demonstrates the relationship between sources of Schumpeterian opportunities (introduction of new information) and the existence of those opportunities. Bhide (2000) explained that about half of the founders of fast growing private companies (from the *Inc 500* list) in the US that he interviewed indicated that they initiated their businesses in response to a change in technology, regulation, or some other external factor. Blau (1987) examined the self employment rate in the USA over two decades and found that an increase in the rate of technological change led to an increase in the self employment rate. Shane (2001) examined inventions patented by the Massachusetts Institute of Technology between 1980 and 1996, and found that more heavily cited patents (a proxy for more new information) were more likely to lead to firm formation (proxy for entrepreneurial opportunities) than less heavily cited patents. If we think of Schumpeterian new knowledge as something new to everyone in the marketplace, then the patent system would, indeed, help in identifying these new pieces of technological knowledge. Based on the previous literature summarized until now, our first hypothesis is as follows:

H1. If all other factors are constant, the greater the degree of technology knowledge in a new venture the larger the number of entrepreneurial opportunities that will be recognized.

2.2.2 Market knowledge. Austrian economists believe that a viable theory of market system – and entrepreneurship – cannot assume equilibrium but must explain how a market achieves equilibrium starting from disequilibrium initial conditions (Kirzner, 1997; Shane, 2000). Disequilibrium enables entrepreneurs to discover market imbalances that offer ways to earn economic rents provided that entrepreneurs can protect their discoveries from imitation by others (Fiet, 2002). In Austrian economists' view, existing idiosyncratic information and knowledge provides the basis for entrepreneurial opportunities.

Austrian economists (Hayek, 1945; Kirzner, 1973, 1997) believe that the possession of information that is appropriate to a particular opportunity leads to discovering this opportunity[2]; people and firms recognize those opportunities related to information that they already possess (Denrell *et al.*, 2003). Shane (2000) finds that three major dimensions of prior knowledge are important to the process of entrepreneurial discovery in high technology context: prior knowledge of markets, prior knowledge of ways to serve markets, and prior knowledge of customer problems. New information about a technology may be complementary with an individual's prior information about how particular markets operate; recognizing an entrepreneurial opportunity related to a specific technology requires prior information about markets. The positive effects of market knowledge in OpR are, according to McKelvie and Wiklund (2004) due to:

- awareness of customer problems as sources of potential opportunities;
- the ease of determining the market value of new technological discoveries or other market changes; and
- increased communicability of tacit knowledge of new technology between user and end-customer.

Based on the existing literature on market knowledge and entrepreneurial opportunities, our second hypothesis is:

H2. If all other factors are constant, the greater the degree of market knowledge in a new venture the larger the number of entrepreneurial opportunities that will be recognized.

Despite the differences in the ways that OpR is discussed in the Schumpeterian vs Kirznerian tradition, some researchers have interpreted the Kirznerian and Schumpeterian opportunity recognition propositions as complementary rather than competing (Blaug, 2000). Some individuals or organizations are so sensitive to market needs or problems that they perceive possibilities for new products continuously in any environment. This sensitivity (or alertness, see, e.g. Gaglio and Katz, 2001) to problems or possibilities does not necessarily extend to generation of ideas for solutions to the problems; not everyone who is good at asking questions is equally adept at creating answers. Other individuals or organizations may be particularly sensitive to identifying un- or underemployed resources, such as unused land, idle production facilities, or unexploited technology or inventions. Having identified such resources, however, these individuals or firms may not be able to define particular uses or users for which the resources could create value. Inventors or scientists may generate ideas for new products and services without regard to the commercial viability of these inventions (Ardichvili *et al.*, 2003) Hence, it is the combination of new technological knowledge (Schumpeterian) and idiosyncratic market knowledge (Kirznerian) that seems to be essential for OpR.

As an example of the combination of the two types of knowledge, consider the invention of polymerase chain reaction (PCR), a biochemistry and molecular biology technique for enzymatically replicating DNA without using a living organism. PCR created the opportunity to manufacture and sell DNA based products (e.g. for the detection of hereditary diseases, the identification of genetic fingerprints, the diagnosis of infectious diseases, and the cloning of genes) in a scale that was unheard of before. The knowledge of this Schumpeterian opportunity suggested that the resources used for PCR were mis-priced and could be profitably recombined into a new form. Hence, the market for resources had moved from an equilibrium to a state of disequilibrium. This disequilibrium, again, and the idiosyncratic information that individuals had about the market potential of PCR based products, created opportunities that were of a Kirznerian type.

A question then arises, if new opportunities are recognized based on Schumpeterian, new technology knowledge, what is the role of idiosyncratic market knowledge in this opportunity recognition process? Even though there are few empirical studies that have investigated the market knowledge – business opportunity link in the entrepreneurship domain, extant research in new product development (NPD) supports the claim that NPD projects, which rely on carefully defined customer needs, are more likely to succeed than those that are "only" based on new technological opportunities (Holt *et al.*, 1984; Cooper, 1993). From marketing research we know that new product opportunities are recognized by firms who stay close to their customers and markets (Athuene-Gima, 1995, 1996; Hurley and Hult, 1998). Hence, to supplement Hypothesis 1 presented earlier, we also hypothesize that:

H3. If all other factors are constant, when a new venture has a higher level of market knowledge, the relationship between the level of technological knowledge and the recognition of entrepreneurial opportunities will be enhanced.

Next, we describe the empirical study carried out to test the three hypotheses.

3. Empirical study

Entrepreneurial opportunities that have been recognized by entrepreneurs are typically developed and exploited within firms. Since unrecognized opportunities are impossible to identify for research purposes, it follows that an empirical research on entrepreneurial opportunities has to look into opportunities within a firm context. Hence, the level of analysis in the current empirical study is a firm.

3.1 Sample

Data were available for 42 biotechnology ventures, which were collected at two points of time. Given that opportunities based on technological knowledge typically take time to develop, there needs to be a time lag between the measurement of the knowledge variables as predictors on one hand (t_1), and recognized opportunities as a dependent variable on the other hand (t_2). The first wave of data collection (in-person interviews) happened between October 2003 and June 2004 (t1). The second wave (mail questionnaire) took place in May-October 2007 (t2). The development timescales in the field of biotechnology are long. For example, the journey of a pharmaceutical product from initial discovery of an active compound to the launch of a drug typically takes 12 to 15 years (Rothaermel and Deeds, 2004). In this light, the time lag of approximately 3.5 years between the first data collection (t1) and the second round of data collection from the same companies (t2) seems justifiable.

Biotechnology was chosen as the empirical field for this research since the lengthy and highly regulated R&D processes make it easier to separate the sources of entrepreneurial opportunities throughout the opportunity recognition process. Also, biotechnology is a growing field of industrial activity, and the growth companies in this sector represent firms that are of interest for governments and politicians because of their high earning potential. The global nature of the biotechnology business and, especially, the international scope of biotechnology markets – be it global markets for medicines or the licensing markets for inventions – make it feasible to assume that despite location, opportunity recognition manifests in the same ways in R&D-intensive biotechnology SMEs. Having said this, there are national differences on the supply side of biotechnology. The role of the public sector in supplying the soft infrastructure of innovation support for enterprises is not uniform from country to country, continent to continent. Because of the potential influence of institutional setting on the opportunity recognition process, data are collected from two geographic areas, namely the US and Nordic countries.

The target population of the survey includes the small and medium-sized independent medical biotechnology companies in Finland, Sweden, San Francisco Bay Area, Philadelphia area and South Florida. These areas were chosen so that firms from different institutional environments (Nordic and American) would be included. Furthermore, some areas have long roots in biotechnology (like Bay Area and Pennsylvania), others have experienced a dominance of large pharmaceutical companies in the past (Sweden), and some areas have only witnessed rapid growth in the biotechnology field over the past decade (Finland and South Florida). Random sampling was used in this study to make the sample similar to the population. The sample was stratified using the following criteria:

- corporate governance (independent firms);
- employment size class maximum of 250 people following the European Union's cutoff for small and medium-sized enterprises;
- industrial sector: active in R&D in human therapeutics (drug discovery and development), diagnostics, medical devices, and/or technology research that helps in developing the aforementioned classes of products; and
- product-orientedness (i.e. even if firms provide services as a part of their business model, their main lines of business are about researching and developing physical products).

The random sample of companies included in this research was derived from the local biotechnology industry databases. Altogether, 193 firms in the chosen geographical areas fulfilled the sampling criteria in 2003. All of these firms were contacted and asked for an interview appointment with the company CEO. A total of 50 companies declined to participate, and it was impossible to establish contact with 49 firms. 94 firms agreed to participate, and interviews were conducted in 85 firms (effective response rate 45 percent) in 2003-2004.

3.2 Data collection method 2003-2004, independent variables

In order to collect valid and comprehensive data from the sample firms, face-to-face interviews were conducted with the CEO (in some cases the business development manager or founder) of each sample firm in wave 1. This was important for a number of reasons. First, in addition to a structured questionnaire, the wave 1 survey instrument included questions that were open ended and the analysis of which has been reported elsewhere. Second, face-to-face contact gave the respondents a possibility to ask for clarification if they did not understand some questions. Third, a personal visit and data collection minimized the amount of missing data.

All interviews were conducted by the second author. The interviewees were told about the general purpose of the research before the interviews, but they were not shown the questionnaires. In the actual interview, the session started with questions about company demographics, after which open-ended questions were presented. Finally, the interviewees filled in the standardized scales (used for analysis in this study) on paper. Overall, the questionnaire worked well and the personal interview approach resulted in a minimal amount of missing data. 85 percent of interviewees were CEOs, founders, or founder-CEOs of their firms. The remaining 15 percent held the title of Vice President of Business development, or equivalent.

Of the total of 85 interviews in wave 1, 58 were conducted in the US. The remaining 27 were divided between Finnish ($n = 20$) and Swedish ($n = 7$) companies. Table I illustrates the distribution of survey responses in wave 1 and wave 2 by geographic region.

A typical sample firm was three to five years old at the time of first data collection, and develops innovations either for the pharmaceutical markets or for use by other companies (technology platforms). Only three sample firms employed more than 100 employees, and half of the firms had not launched any products by

	Wave 1	Between wave 1 and wave 2			Wave 2		
Firm location	Original N in phase 1	Quit or no record	Merged/ acquired	Effective N 2007	Reply by mail	Reply after phone inquiry	Effective response rate phase 2 (%)
Finland	20	2	4	14	4	9	93
Sweden	7	0	1	6	4	1	83
Bay area, CA	26	2	6	18	3	7	56
Pennsylvania	13	1	2	10	7	2	90
South Florida	19	3	4	12	5	0	42
Total	85	8	17	60	23	19	70

Table I.
Survey response by geographic region

the time they were first interviewed. Even out of the firms that did have some sales revenue many indicated that their most promising products were yet to be launched. The US-based sample firms are larger (number of employees) and exhibit higher levels of entrepreneurial orientation than their Nordic counterparts. No other significant differences were detected between American and Nordic sample firms.

3.3 Data collection method 2007, dependent variables

The purpose of the second wave of data collection was to follow up with the firms first interviewed in 2003-2004. Data collection started in May 2007 by secondary data collection from online sources to determine the status of each firm and original respondent. As illustrated in Table I, 60 of the original 85 firms were still operating as independent businesses. In 43 of these 60 firms the interviewee from 03-04 was still in the same position or had even been promoted. In these 43 cases, a questionnaire was mailed to this individual. In the remaining 17 cases the new company CEO received the questionnaire. Mail survey was employed because it allowed a maximum amount of information to be collected from a maximum number of geographically dispersed firms in a minimum amount of time. A total of 42 companies provided usable data in this second wave of data collection (response rate 70 percent).

3.4 Operationalization of variables

A pilot study was completed in order to test the instruments used, and ten firms participated. The final operationalizations of the study variables are reported in Table II.

Market knowledge. The measurement of market knowledge is based on a widely used behavioral market orientation scale, originally developed by Kohli *et al.* (1993). This measure captures the behaviors of a firm that are geared towards understanding customers and competitors throughout the company. Hence, it captures the firm's knowledge of customers, markets, and ways to serve markets (Shane, 2000). The scale developed by Kohli *et al.* (1993) has been subsequently employed in a wealth of

Construct	Variable(s)	Scale, data source etc.
Market knowledge	Market intelligence generation and dissemination in firm measured in 2003-2004	22-item scale based on Kohli *et al.* (1993). Scale: Mean of 22 variables selected after measure refinement ($\alpha = 0.753$)
Technology knowledge	Number of patents (approved) by June 2004	Self reported by interviewees, checked against USPTO database (log)
Entrepreneurial opportunities recognized	New inventions between June 2004-May 2007 Therapeutic areas where these inventions are useful Domestic patent applications between June 2004-May 2007 International patent applications between June 2004-May 2007	Self reported by interviewees. Scale: Mean of the four variables (log) ($\alpha = 0.882$)

Table II.
Operationalization of study variables

empirical studies in the field of marketing (For example, Matsuno *et al.*, 2002; Kyriakopoulos and Moorman, 2004; Kara *et al.*, 2005). The 18 market intelligence generation – and dissemination – items from the measurement by Kohli *et al.* (1993) were further developed to reflect the current empirical context, i.e. small, young biotechnology firms. These refinements were based on insights developed in six preliminary case studies, completed by the second author, as well as pilot testing of the instrument. Instead of "business unit" (the original focus of Kohli *et al.*, 1993) the items were re-worded to reflect the firm. Other changes to the original scale are outlined in Renko (2008) and Renko *et al.* (2009). The final 22-item market knowledge scale has a Cronbach's alpha value of 0.753.

Technology knowledge. Patents are output measurements of technological knowledge (Coombs and Bierly, 2001). In biotechnology, most new technology is protected by patents. Patent data are used here as a proxy for technology knowledge. The patent data provided by the interviewees were checked against the publicly available USPTO data (correlation coefficient 0.433, significant at $p < 0.01$). Since the smallest firms' patents that have been granted to, e.g. universities or scientists instead of these startup firms may go unnoticed in company name searches in the USPTO database, a mean of self-reported and publicly available patent numbers was used in analyses. Patent citation data were also considered as a possible proxy for technology knowledge (Shane, 2001). Unfortunately, because of the young age of the sample firms and their patents, only patents of 14 firms have received citations by today. Hence, the use of citation information was omitted at this stage.

Entrepreneurial opportunities recognized. Given the ambiguity surrounding the entrepreneurial opportunity construct, it is not surprising that only a few researchers have tried to turn entrepreneurial opportunities into measurable units. For those who have tried, new firm startups seem to be the place where individuals reside after having recognized entrepreneurial opportunities. Hence, our choice of startup firms in the field of biotechnology as the data source concerning entrepreneurial opportunities is in line with previous research (Busenitz, 1996; Singh, 2000; Park, 2005; Saemundsson and Dahlstrand, 2005; Ozgen and Baron, 2007).

In line with the definition established for entrepreneurial opportunity recognition in this research, new product development process can be an example of an entrepreneurial opportunity. To quantify the opportunities recognized by the sample firms we should look into their product development pipelines to count the number of opportunities. In order to understand the variables chosen to reflect entrepreneurial opportunities in the current empirical context the reader should have a general understanding of new product development processes in biotechnology. In the development pipeline typical for biotechnology products, the projects evolve from discovery (invention) and scientific development via clinical development and commercialization. The development from invention and preclinical testing to a commercialized product typically takes 12-15 years for biomedical products. One aspect related to the complexity of the biotechnology innovation process is that there is not normally a one-to-one relationship between a specific scientific discovery and a certain industrial application. Any given biotech invention may be used in a variety of applications and industries (McKelvey *et al.*, 2004), and often firms have to select which one of the many potential commercialization avenues they want to pursue for any one invention. Having defined entrepreneurial opportunity recognition as perceiving a possibility to introduce innovative (rather than imitative) goods or services to a marketplace through:

- the founding and formation of a new venture; or
- the significant improvement of an existing venture.

It follows that recognized entrepreneurial opportunities in biotechnology ventures have the following characteristics:

- novel (invention);
- patentable (potential industrial use); and
- lead to a significant improvement of the venture.

Hence, the following four items were selected as scale items for "Entrepreneurial opportunity recognition":

(1) Number of new inventions for which the firm has filed domestic or international patent application(s).
(2) Number of therapeutic areas where these inventions are useful.
(3) Number of domestic patent applications.
(4) Number of international patent applications.

Respondents in wave 2 were asked to provide numbers since June 2004 only. It is assumed that these inventions then have a potential to lead to significant improvement of an existing venture. Especially those that have potential use in multiple therapeutic areas can be valuable since a firm can license out development rights to those indications it does not pursue in house. The four-item scale has a Cronbach's alpha reliability value of 0.882.

4. Results

The sample size of 42 companies presents some challenges in terms of statistical conclusion validity. However, the fact that the units of analysis, and, more importantly, respondents, represent a relatively homogenous group of companies in terms of firm demographics should increase the statistical conclusion validity.

Multiple linear regression analysis was used to assess the relationship between the dependent variable and the independent variables. The main assumptions for using multiple linear regression are normality of the variables, homoscedasticity, and independence of the independent variables. The normality of the variables was tested by assessing the normality of distribution graphically with the help of normal probability plots. The findings of each assessment were additionally verified by means of the Kolmogorov-Smirnov test for normality. The homoscedasticity of the variables is tested using Levene's test. Variance-stabilizing transformations were applied in order to achieve equal variances in cases where heteroscedasticity was present. When running the regression analyses, we used the VIF value to assess multicollinearity. All the VIF values were comfortably low (below 1.3). Tables III and IV show the correlations and the results of the regression analyses. Standardized beta-coefficients are reported in the regression table.

Table IV shows the tests of hypotheses 1 and 2. In Model 1 (see Table IV), only control variables of firm location, size and age are introduced to the analysis. At the next step after the control model, the main effect variables are added to the model (Model 2). Patent count is a significant ($p < 0.05$) and positive predictor of subsequent opportunity recognition, and market knowledge is marginally significant and positive ($p < 0.10$). As a conclusion, we find support for *H1* and marginal support for *H2*.

H3 predicts that the relationship between technology knowledge and entrepreneurial opportunity recognition is contingent on the amount of market knowledge that the organization has. To avoid multicollinearity problems that often emerge when introducing interaction terms to a regression analysis (Aiken and West, 1991), we conducted a univariate ANOVA to test this hypothesis. For the ANOVA, market knowledge and patents (technology knowledge) were categorized into two groups of equal size, respectively. However, because of the small sample size, the ANOVA results were not significant. Still, the interaction of the two variables (depicted in Figure 1) suggests that with a larger sample size this interaction may become significant. Essentially, this figure shows that the positive effect of technological knowledge (higher patent count) on entrepreneurial opportunity recognition is stronger among those firms who also have high levels of market knowledge. Because of the lack of statistical power, however, we find no support for *H3* in the current sample.

	Variables	Mean	s.d.	1	2	3	4	5	6
Wave 1	Patents (log)	1.18	1.35	1					
(2003-	Market knowledge	3.792	0.462	0.27*	1				
2004)	Location, USA	0.68	0.468	0.17	0.03	1			
	Firm age	6.09	3.841	0.17	−0.15	−0.18	1		
	Firm size (number of employees) (log)	2.99	1.15	0.38**	0.24*	10	0.22*	1	
Wave 2 (2007)	Entrepreneurial opportunities recognized (log)	1.54	1.28	0.28	0.32*	0.45**	−0.20	0.42**	1

Notes: *Correlation is significant at the 0.05 level (two-tailed). **Correlation is significant at the 0.01 level (two-tailed)

Table III. Correlations for dependent and independent variables in the regression analysis (Pearson) ($n = 42$)

	Control variables Model 1	Main effects Model 2
Location, USA	0.47***	0.47***
Firm age	−0.20	−0.31**
Firm size (log)	0.36***	0.36***
Patents (log)		0.30**
Market knowledge		0.21*
R-square	0.43	0.56
Adjusted *R*-square	0.39	0.50
Change in *R*-square	0.43***	0.13**
F-value	9.2***	8.7***

Notes: ***Significance $p < 0.01$, **Significance $p < 0.05$, *Significance $p < 0.1$

Table IV. Regression results. Dependent variable: entrepreneurial opportunities recognized. 3.5 year time lag

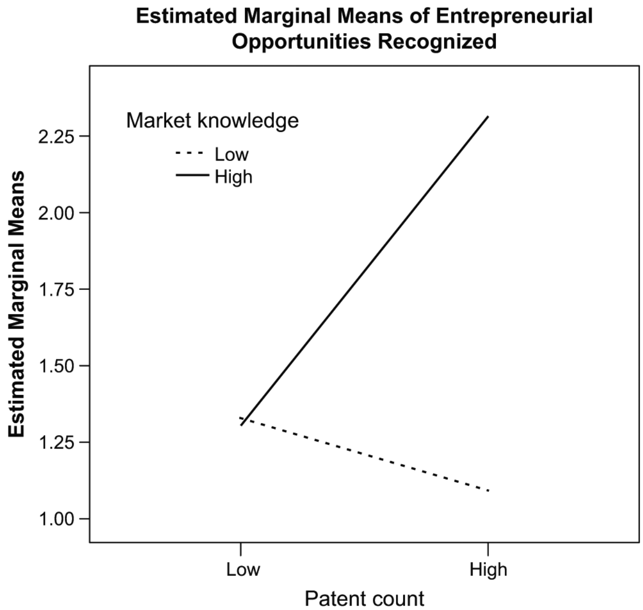

Figure 1.
The interaction of technological knowledge (patents) and market knowledge in influencing entrepreneurial opportunity recognition

5. Discussion and conclusions

To summarize the findings of the empirical study, we find evidence that technology knowledge (captured in the form of patents) does, by itself, contribute to subsequent opportunity recognition. In addition to being evidence of the importance of Schumpeterian-type "new knowledge" in opportunity recognition process, this finding can also be regarded as evidence of the existence of absorptive capacity in these firms. Based on Cohen and Levinthal's (1990) definition, "absorptive capacity is the ability to recognize external information, assimilate this information, and apply it to commercial ends" (pp. 128). Research activity in a firm has a dual role of generating new knowledge and enhancing a firm's ability to absorb new knowledge generated by others (Cohen and Levinthal, 1989, 1990). The more entrepreneurs and their firms have previously absorbed in terms of technology knowledge, the greater their absorptive capacity. Hence, also absorptive capacity hypotheses would expect to see a link between a firm's patenting activity (as a proxy for technology knowledge) and its subsequent capability to recognize entrepreneurial opportunities (see also Alvarez and Busenitz, 2001).

Possibly because of our small sample size we did not find support for the hypothesis that the influence of technology knowledge on opportunity recognition would be moderated by market knowledge. However, the patterns in our data do suggest that the positive linear relationship between technology knowledge and entrepreneurial opportunity recognition only exists when a firm also has a high level of market knowledge. Examining this relationship in a larger sample provides an interesting topic for future research. If future research confirms this interactive relationship it would actually contradict much of the previous literature, which has suggested that when dealing with radically new technology knowledge and developing radically new products – like the sample ventures are doing – conventional market knowledge would be of limited utility. Specifically, previous research often suggests that customers have limited domains of expertise and may be unable to articulate their underlying needs (Hamel and Prahalad, 1991; Leonard-Barton, 1995; O'Connor, 1998; Im and Workman, 2004). However, patterns in our data suggest that a mere understanding of technology and science is not enough for entrepreneurial opportunity recognition. In order for entrepreneurs or entrepreneurial firms to recognize business opportunities they need to understand markets and customers in addition to technology (Shane, 2003; Renko *et al.*, 2009;). Indeed, our empirical analysis shows that market knowledge is a significant and positive – albeit weaker than technological knowledge – predictor of subsequent opportunities recognized in biotechnology ventures (see Kirzner, 1997; Shane, 2003).

While a clear juxtaposition of the creation vs discovery view of opportunity recognition (Alvarez and Barney, 2007) may be beneficial for illustrating the conceptual differences between the two approaches, in reality one can identify elements of creation, discovery, as well as effectuation (Sarasvathy, 2001) in most new firm startups. This study concurs with the view that entrepreneurial opportunities can be discovered both based on a technological innovation (Schumpeter, 1934; Drucker, 1985), in which case the supply of technology is known and demand is unknown (Sarasvathy *et al.*, 2003), as well as because different market participants have unequal access to information about the market conditions (customers, markets, and ways to serve markets) (Kirzner, 1973, 1997; Shane, 2003), in which case the demand in the market is known to some, but the supply has to be developed. Both market knowledge and technology knowledge benefit opportunity recognition.

The data in this study were collected from a single industry, namely medical biotechnology. Biotechnology markets are a prime example of markets for technology (Arora *et al.*, 2001). In addition to biotechnology there are numerous fields of business that share similar market features typical of markets for technology, like the growing market for chip design modules in the semiconductor business as well as the software and chemical processing markets. These industries rely heavily on science and technology, and are dynamic fields where companies constantly need to reinvent themselves to stay in the forefront of competition. These similarities lead to the conclusion that even though biotechnology is, in many respects, a special kind of industry, the relationships detected in the empirical study should be applicable in some other contexts as well.

The main limitations of this study include single informant bias and limited statistical conclusion validity as a result of the small sample size. The single informant problem is typical for studies conducted in small firm settings. In this study, comparisons of patent figures reported by the interviewees with data from secondary sources were completed to ensure the reliability of the data. These comparisons indicate that even though the self-reported numbers are not exactly similar to those available from the secondary sources, there is no evidence that the measurements used would be biased estimators. Regardless of the small sample size, a longitudinal study provides a better understanding of the nature of the relationships between constructs than what a cross sectional study would. Within a longitudinal sample of young ventures the amount of company exits between data collection efforts is, unfortunately, bound to be substantial.

In conclusion, we have shown that both technology knowledge and market knowledge contribute to opportunity recognition in new-technology based ventures. Firms that identify numerous entrepreneurial opportunities have high levels of both market knowledge and technology knowledge. This finding is in line with, for example, the suggestions of Amabile (1999), who stressed the importance of combining market knowledge and technology knowledge in the development of new ideas. We also concur with those numerous research insights from the new product development literature that emphasize the role of divergent knowledge types in recognizing and developing opportunities (Holt *et al.*, 1984; Rothwell, 1992; Cooper, 1993; O'Connor and Veryzer, 2001;). Future research in the field of opportunity recognition should boldly tackle the challenge of operationalizing concepts such as alertness, heuristics, knowledge based resources, entrepreneurial opportunity recognition, and exploitation in multiple contexts. A wealth of conceptual literature, including many conceptual models waiting to be tested empirically, already exists, presenting exciting opportunities for future research.

Notes

1. Some other authors essentially talk about the same division between Kirznerian and Schumpeterian opportunities when they use the terms opportunity discovery vs opportunity creation (e.g. Alvarez and Barney, 2007).
2. Note that the terms like opportunity identification or opportunity discovery, widely used within the Kirznerian tradition, involve passive search or accidental discovery. The fundamental assumption is that opportunities exist by themselves in the environment and can be discovered. Also, it is impossible for actors to actively search for opportunities that cannot be clearly defined ex ante.

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