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Imprints from idea generation on innovation and organizational strategic selection

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Abstract

This study builds on the innovation and organization literatures to examine how innovation origin and selection behave at intersections and influence the nature of innovation outcomes. Specifically, we focus on how the strategy of the organization where the idea is developed (i.e. the organizational environment in which the project is developed) reinforces or erodes the imprinting from idea generation (i.e. the knowledge sources at the project?s origin) on the nature of innovation outcomes. We use data from a survey to Italian inventors on the process of innovation development of two types of innovations: market exploitative innovations and technological exploratory innovations, which are allowed to overlap. Results suggest that the organizational environment in which the project is developed moderates the effect of the original knowledge sources on the innovation outcome. The imprinting effect of ideas on innovative outcome is shown to be stronger for smaller firms than for large firms. Individual and market ideas developed in sole or small ventures interact favorably to create incentives for exploitation of market opportunities. Ideas coming from scientific activities and developed at sole or small ventures are instead associated with exploration of technological novelty.

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This study builds on the innovation and organization literatures to examine how innovation origin and selection behave at intersections and influence the nature of innovation outcomes. Specifically, we focus on how the strategy of the organization where the idea is developed (i.e. the organizational environment in which the project is developed) reinforces or erodes the imprinting from idea generation (i.e. the knowledge sources at the project's origin) on the nature of innovation outcomes. We use data from a survey to Italian inventors on the process of innovation development of two types of innovations: market exploitative innovations and technological exploratory innovations, which are allowed to overlap. Results suggest that the organizational environment in which the project is developed moderates the effect of the original knowledge sources on the innovation outcome. The imprinting effect of ideas on innovative outcome is shown to be stronger for smaller firms than for large firms. Individual and market ideas developed in sole or small ventures interact favorably to create incentives for exploitation of market opportunities. Ideas coming from scientific activities and developed at sole or small ventures are instead associated with exploration of technological novelty.

1. Introduction

The literature is extensive in arguing and showing that an innovation emerges at the intersection of *origin* and *selection* (Nelson and Winter, 1975; Dosi, 1982), involving a cumulative learning process that results from the recombination of external and internal and codified and tacit pieces of knowledge (Levitt and March, 1988; Nonaka, 1994). Innovation *origins,* including knowledge sources at the innovation project's origin, represent the founding conditions that are deterministic of the nature of innovations, as their imprints persist across innovation development process (Johnson, 2007; Marquis and Tilcsik, 2013). The *selection* of ideas throughout the innovation development process is affected by the strategy and the managerial systems of the organization in which the innovation is developed, and by the development and dynamics of the industry and technology as a whole (Dosi, 1982; Leonard-Barton, 1992; Tripsas, 1997). *Origin* and *selection,* then, are argued to affect the nature of the resulting innovation development process, which can lead to innovations that explore technological novelty or innovations that exploit market opportunities, or both (Riggs and von Hippel, 1994). However, we still know very little about when and how organizational strategy might erode or reinforce the imprints of the original idea on innovation, which might be instrumental to advance existing knowledge on the exploratory versus exploitative nature of innovations. The present study addresses this gap by examining how the *origin* of the innovation development process and its *selection* intersect; specifically it explores if organizational strategy reinforces the imprints of the innovation origin or if, instead, they attenuate the imprints of the original innovation idea on the nature of the innovation that is being developed.

Prior literature has shown the impact that imprints or origin have on the overall performance of firms or individuals. For example, ventures founded by highly educated entrepreneurs have been shown to live longer (Bates, 1990). Founders' specific knowledge, experience and ties were shown to have a lasting effect on their venture's performance (McEvily et al., 2012). The ideation of the venture and the diversity of the pre-entry opportunity portfolio have a lasting effect on firms' potential growth and diversification (Gruber et al., 2003; Hsu and Lim 2014). Focusing specifically on the relationship between the distance of technological origin and the innovative outcome using patent data, Phene et al. (2006) have shown that simultaneous exploration of distant technological and geographic knowledge is not helpful to generate breakthrough innovations, while Arts and Veugelers (2013) have shown that breakthroughs are associated with the breadth of the recombination of technical knowledge from many different technology fields and non-technical knowledge.

Further, strategic decisions to select ideas and pursuit certain innovation development paths have been shown to impact the nature of innovations (Leonard-Barton, 1992; Burgelman, 1994), and to be different across large established firms and new and young ventures (Tushman and Anderson, 1986; Henderson and Clark, 1990; Rothaermel, 2001). Large established firms' complementary assets and large customer basis were shown to permit large returns from exploitative innovations. However, sometimes these resources also limit large established firms to change their innovation strategy and their managerial systems in order to enter in new sub-product markets (Leonard-Barton, 1992; Tripsas and Gavetti, 2000).

While the literature has shown that the *origin* and *selection* of innovative ideas might direct the innovative efforts towards the exploration of technological novelty or the exploitation of market opportunities, it has neglected the effect of the intersection between the original idea imprinting and the strategic selection. Hence, we still know very little about the tensions between *origin* and *selection* along the innovation development process. It is of particular interest for the organization and management of the process of innovation development to understand if selection decisions act complementary to the original idea or instead if they neutralize original idea imprinting on the innovation development process (Sydow et al., 2009; Marquis and Tilcsik, 2013).

The present study focuses on the intersection of the imprint of the knowledge sources at the origin or conceptualization of the innovation and the strategic organizational environment in which the idea is developed, and their effects in directing innovative efforts towards the exploration of technological novelty or towards the exploitation of market opportunities. We propose and provide evidence that the nature of knowledge sources that were at the origin of the conceptualization process and the organizational structure in which the invention was developed interact to affect the nature of the inventive and innovative process. Organizational flexibility and lack of strong financial incentives associated with the loss of established customer basis create a selection environment that reinforces the effect of knowledge sources on the nature innovation. Instead, selection environments characterized by organizational, financial and market rigidities are more likely to attenuate the imprinting effect of knowledge sources (Bulgerman, 1994; Riggs and von Hippel, 1994).

Empirically, we rely on data from a survey of Italian inventors that investigated the development process of two types of industrial inventions: innovations with highest market value and innovation for which university knowledge was of greatest importance. We operationalize our research question by focusing on the mechanism and processes that lead to market exploitative innovations, technological explorative innovations, or both. Given that university knowledge is often understood as less applied and particularly important for solving technological problems during the innovation development process (Cohen et al., 2002), innovation for which university knowledge was of greatest importance is used as a proxy for technological explorative innovations. Innovations with highest market value represent successful market exploitative innovations. By having information on the two types of innovation for each industrial researcher our data permit to control for characteristics of the inventors that affect the processes of knowledge origin and selection underlying the innovation development (Foss, 1996; Felin and Hesterly, 2007; Rothaermel and Hess, 2007). We use bivariate probit regressions to simultaneously estimate the development of market or technological breakthrough inventions.

We find that project ideas based on internal R&D and market knowledge sources are more likely to lead to innovations aimed at exploiting market opportunities than those relying on scientific or individual knowledge sources. The organizational environment in which the project is developed moderates the effect of the original knowledge sources on the innovation outcome. The imprinting effect of ideas on innovative outcome is shown to be stronger for smaller firms than for large firms. Individual and market ideas developed in sole or small ventures interact favorably to create incentives for exploitation of existing technological and market opportunities, thus on the achievement of innovations with the highest market value. Ideas coming from scientific activities and developed at sole or small ventures are instead associated with exploration of technological novelty.

The paper is organized as follow. Section 2 reviews the literature on the behavior of imprints and strategy along the innovation development process with aim to derive expectations on the how they interact to affect the innovation outcomes. Section 3 presents the methodology and data used in this study. Section 4 reports the results. Section 5 concludes the paper.

2. Tensions at the intersection of the innovative process: idea generation and selection

2.1 The nature of innovation

The most studied tension in organizational research is the one observed between exploration and exploitation objectives and innovative efforts (eg. Benner and Tushmann, 2002, 2003). Some evidence suggest that organizations tend to develop internal structures that create incentives for more exploratory or more exploitative innovation decisions, reinforcing successful prior experience with specific approaches (Leonard-Barton, 1992; Sull, 1999). Focus on existing market structures and technologies drives new product success and allows companies to exploit their existing market (Im and Workman, 2004). Exploratory innovations on the other hand aim to advance into new markets and technologies, potentially breaking with existing customers and can be considered as "technology-push" innovations (Benner and Tushmann, 2002, 2003; Zhou et al., 2005).

Success in the commercialization of such technological exploratory innovations is highly uncertain and therefore they often do not lead to market exploitations (Gibbons and Johnston, 1977; Mowery and Rosenberg, 1979; Dosi, 1982; Schmoch, 2007). Ancillary innovations are needed to perfect the first breakthrough and to make its application feasible (Nerkar and Roberts, 2004; Golder et al., 2009). Commercialization of exploratory innovations requires the recombination of different types of knowledge related to the technological breakthrough and to demand and markets (Dosi, 1982; Kogut and Zander, 1992; Henderson and Cockburn, 1994; Rodan and Galunic, 2004). It has been shown to depend both on firms' social capital that provide it with insights and information both on the market potential, as well as on technological and science developments (von Hippel, 1994; Phene, et al., 2006; Baba and Walsh, 2010).

The literature is then consensual in arguing that the possibility of a technological breakthrough becoming a market successful innovation depends on the technological, organizational and relational capabilities of firms to recombine different types of knowledge, as well as on market conditions. More than differing in the product development stage that they reach, technological exploratory innovations and market exploitative innovations differ in the nature of underlying knowledge and the process of idea-generation, selection and development that they experience (Gibbons and Johnston, 1977; Dosi, 1982; Zhou et al., 2005).

New product ideas are generated based on different knowledge and information sources, in particular they might be differentiated in terms of distance to firms' technological and market knowledge bases. However, there does not seem to exist any one to one relationship between the origin of the innovative idea and the nature of innovation developed (Gibbons and Johnston, 1977; Mowery and Rosenberg, 1979; Dosi, 1982; Schmoch, 2007). Still, the knowledge and information on which ideas for innovation development rest seem to influence the innovation outcomes of different ideas (von Hippel et al., 1999; Phene et al., 2006).

Further, the organizational environment in which innovations are developed defines the system of incentives that frames individuals' search and selection of ideas and development paths (Rosenberg and Nelson, 1994; von Hippel, et al., 1999; Nonaka et al, 2000; Zhou et al., 2005). Various organizations have different strategies and managerial systems; consequently provide incentives to the development and selection of specific types of knowledge, to specific processes of idea-generation, and to innovation (von Hippel, et al., 1999). Large established firms and small or new ventures develop different managerial systems and strategies for technology development and innovation (Leonard-Barton, 1992; Tushman and Anderson, 1986; Henderson and Clark, 1990). These differences reflect on their capabilities and capacities, which influence an individual's possibilities to develop certain types of ideas rather than others (Teece, 1986; Cohen and Levinthal, 1990). Individuals that work in large established firms or in small or new ventures have different resources and face different types of knowledge incentives. The outcomes of their inventive process reflect the prevalent structure of organizational incentives and capabilities which are designed to achieve specific strategies (O'Connor and De Martino, 2006; Tushman and Andersen, 1986).

We can thus expect that the technological exploratory innovations and market exploitative innovations have been exposed to different tensions during the idea-generation (in terms of knowledge sources they rely on and in terms of knowledge combinatory processes they include) and idea-selection processes (in terms of the organizational incentives to use certain selection criteria and development efforts towards technological/market objectives). Hence, we expect that the same original idea to develop differently in organizations with specific managerial systems and innovation strategies. In what follows, we will develop our expectations of the effect of idea generation and idea selection on innovation outcomes.

2.2. Idea generation process: Imprint from the knowledge origin

The inventive and innovative process involves recombination of different types of sticky knowledge, including basic and applied knowledge, scientific, technological, operational and marketing knowledge developed within or outside the organization (Dosi, 1982; Kogut and Zander, 1992; Henderson and Cockburn, 1994; von Hippel, 1994). Individuals and organizations develop projects based on ideas resulting from different types of knowledge sources. Ideas for new products and technology have at its genesis knowledge that was developed through the company's R&D activities, but also knowledge that was provided by suppliers, customers or by the firm's commercial and operational activities. Additionally, it includes more distant knowledge sources such as intuition and serendipitous associations of the individual researchers as well as knowledge that was developed or co-developed with universities and PROs (Mansfield, 1991, 1998). Original ideas for R&D projects resulting from knowledge of different nature may contribute differently to the development of breakthroughs (Arts and Veugelers, 2013; Phene et al., 2006). Next, we discuss and derive expectations on how different types of knowledge and information sources on which ideas for product and technological development rely affect the nature of the innovation developed.

Internal R&D knowledge sources

The main objective of industrial R&D activities is to sustain the current and future market needs of the firm. Hence, they focus on the search for knowledge and proof of concept that can be used as technological inputs for developing new or improved products as well as supporting the production of high quality products. Industry R&D activities, thus, focus on applicability, on search for knowledge that allows firms to solve a specific technological problem and to develop commercially viable products, and consequently improve their market position, and their level of value appropriation in the market (Rosenberg and Nelson, 1994; Nonaka et al, 2000). Many companies also complement their applied R&D activities by investing in basic research in order to develop absorptive capacity to use externally developed knowledge, to catch up with technical advances, to develop technological capabilities and social capital to access different knowledge and resources, and to create technological options that can be pursued in the future (Cohen and Levinthal, 1990). Even when investing in basic research, the firms' objective is to improve their capabilities and to increase opportunities to develop commercially viable technologies and products (von Hippel et al, 1999). Ideas for product and technology development that had at the genesis knowledge developed by the company's research activities might be able to lead to innovations that are compatible with the firms' existing knowledge and assets (Tushman and Anderson, 1986; Henderson and Clark, 1990; Tripsas 1997, von Hippel et al., 1999).

Market knowledge sources

Further, external knowledge and information accessed through the interaction with other market players in the pursuit of operational and commercial activities permit access to relevant sources for firms' innovation development (von Hippel, 1994; Laursen and Salter, 2006). Cohen et al (2002) show that a majority of R&D projects leading to innovations tend to be based on ideas resulting from firm's operational and commercial activities, hence from firm's interaction with other market actors. Customers, for example, have sticky knowledge on how a product is used, on product functionalities with higher value, as well as on the most valued improvements in functionality and performance of existing products (von Hippel, 1986; Lilien et al., 2002). Suppliers, on the other hand, have specific knowledge on technologies and components that are used or can be used by the focal firm (Clark, 1989). In addition, both suppliers and customers may undertake R&D activities which can provide insights and information to the focal firm on potential improvements or new products. Hence, interactions with other market actors in the pursuit of operational and commercial activities, in particular with customers and suppliers, may provide an opportunity for the transfer of sticky information on the customers' current needs, on technological opportunities, or on expectations for new or improved products (von Hippel, 1994). However, customers may not be able to provide information on new markets or technologies (von Hippel et al., 1999). Through their operational and commercial activities the focal firm can thus collect information on existing and potential demands, as well as on ways of improving their existing product portfolio. Such insights are beneficial for a better exploitation of the firm's existing market. However, the focus on existing markets ignores new, emerging markets and may hinder the development of novel exploratory lines of research (Slater and Narver, 1995; Im and Workman, 2004; Zhou et al., 2005).

Individual knowledge sources

Many innovations have their origin in fortunate accidents resulting from intuition and experience of creative, enthusiastic and persistent inventors. Ideas for new projects often result from the combination of different problems and solutions. These ideas often result from the specific R&D training or work experience, personal interests and curiosity of individual inventors (Cunha et al., 2010). Contrary to ideas that come from the research activities of firms and universities or from the operational and market activities of the firm, these ideas may be characterized by a great variance in terms of feasibility, applicability and potential market exploitability. Hence, ideas for technological solutions and innovations resulting from serendipity might be less likely to result in innovations than ideas based on knowledge sources close to the firm capabilities and activities.

On the other hand, literature has acknowledged the importance of creative, enthusiastic and persistent inventors for innovation and there is evidence that such productive individuals are very important for technological advancement and they contribute most to a firm's success (Gay et al., 2010; Rothwell, 1992). Thus, innovations that have at origin creative ideas or intuition of individuals may not only result in technological but also in market success.

Scientific knowledge sources

Scientific and technological knowledge developed by universities and PROs are occasionally brought to the market (Stokes, 1997). University knowledge is publicly available once universities and public researchers have incentives to diffuse it through publications, conferences or through R&D collaboration (Callon, 1994; Cohen et al., 2002). Still, as some authors point out, to access and use this knowledge firms and individuals need to have related knowledge (Cohen and Levinthal, 1990; Cowan et al., 2000; Foray and Steinmueller, 2003). Universities and PROs focus on the development of basic knowledge without identifying areas of applicability, with the main objective of increasing understanding of fundamental principles and relationships (Callon, 1994). They are however often involved in proving concepts for applied research and in prototyping, hence at exploring the applicability of theorems and principles to a specific problem (Rosenberg and Nelson, 1994). Given researchers' focus on extending existing fundamental knowledge and exploring its applicability, knowledge developed or co-developed by universities and PROs is likely to inspire technological developments within the firm that can lead to technological breakthroughs. Previous empirical research indeed found that private sector firms that source ideas from academia gain benefits for their technological innovations (Nelson 1986; Jaffe 1989; Mansfield 1995, 1998; Narin et al. 1997; Hall et al. 2000; Salter and Martin 2001).

Based on the above, and given the nature of these different idea origins, we expect that ideas for product and technological development based on knowledge distant from the organization's strategy might be particularly difficult to be used in the development of successful market exploitative innovations (Leonard-Barton, 1992). Specifically, idea-generation process based on industrial R&D and market and operational activities information sources (i.e. ideas based on knowledge close to the organization capabilities) may be more likely to direct the innovation search towards market applicability, while idea-generation based on serendipity and university knowledge (i.e. ideas based on knowledge distant from the organization), may be more likely to direct the search towards exploration of new technology knowledge, and the development of proof of concept. Hence, we expect:

H1: Ideas originating from knowledge closer to technological and market activities of the firm are more likely to lead to market exploitative innovations (greatest market value) while ideas originating from scientific and individual knowledge sources are more likely to lead to technological exploratory innovations.

The organizational prevalent strategies and managerial systems influence the idea selection and the form in which different ideas for problem solving and product development are pursuit, and consequently the nature of the innovations developed. Organizational environments, where specific innovation strategies and managerial systems are prevalent, seem to be particularly suited to select and develop idea generates through specific processes, and consequently to be more or less likely to develop market exploitative or technology exploratory innovations (Tushman and Anderson, 1986; von Hippel et al., 1999; von Hippel and von Krogh, 2003). Next, we discuss how the environment in which ideas are selected and develop can attenuate or reinforce the imprints from the knowledge sources on the nature of innovation.

2.3. Idea selection and development: The moderate role of organizations' strategies

The characteristic that is most used to differentiate firm's strategy and managerial systems is size. Large established firms and small (especially those young) firms are environments with different research and innovation strategies and different managerial systems; hence these different organizational environments are expected to influence the processes of idea generation and selection, as well as the development process (Burgelman, 1994; Riggs and von Hippel, 1994; Tushman and Anderson, 1986; Henderson and Clark, 1990). In other words, the organizational environments in which the ideas are developed are expected to interact and moderate the effect of the idea-origin on innovation outcomes.

Large longer established firms

Large longer established firms that have managerial systems and great installed assets do not always lead on introducing market breakthrough (Leonard-Barton, 1992; Tripsas, 1997; von Hippel et al., 1999). They have mature organizational structures that often create rigidities to the exploration of promising but radically different technological solutions and market products (Henderson and Clark, 1990; Sull, 1999; Tripsas and Gavetti, 2000). Certain ideas and innovations require specific organizational structures and capabilities to be developed which established firms may have more difficulty to provide. Additionally, even if they have developed prototypes of new disruptive technologies, they tend, for a period, to resist cannibalizing their own markets and products (Klepper, 2001; Agarwal et al 2004; Klepper and Sleeper, 2005).

Thus, long established firms may be keener to select ideas that permit to exploit their competences and complementary assets, hence to pursue innovation development paths based on ideas generated by their ongoing R&D, market and operational activities, especially those that target existing markets, and to turn them into market breakthroughs (Teece, 1986; Tushman and Anderson, 1986; Tripsas and Gavetti, 2000). Innovation development paths inspired by knowledge and information further removed from the firm knowledge base, conversely, are less likely to be pursued by long established firms (Henderson and Clark, 1990; Sull, 1999; Tripsas and Gavetti, 2000). Hence, ideas based for instance on market sources, on employees' serendipity or on university knowledge (from academic publications or from formal and informal interaction with university researchers) might decay in large established firms while ideas based on internal R&D activities might be reinforced.

Small and young firms

Often individuals create their own business to develop and commercialize promising ideas that their employers are unwilling to pursue. Founders have prior information and capabilities that allows them to identify and value these opportunities (Klepper, 2001; Klepper and Sleeper, 2005). Despite their reduced access to complementary assets, entrants often launch innovations that open up new markets. The flexibility and the relative immaturity of the organizational structures of young and small ventures provide an adequate environment for the pursuit of promising ideas, especially of those that are too distant from the technological and market knowledge of larger and longer established firms (Agarwal et al 2004; Franco, and Filson, 2006). Such entrepreneurial ventures may undertake more risky development that can lead to exploitative as well as exploratory innovations.

Thus, small firms or start-ups provide a favorable environment to the development of ideas based on the experience, training, and serendipitous associations of its founders. Also ideas resulting from the R&D, operational and market activities of established firms could find an appropriate location in small and young ventures to be developed. New and small ventures also often take on the development of ideas that result from academic research (Link and Scott, 2005; Lockett and Wright, 2005) and have a higher probability of benefiting from collaboration with academic researchers (Mohnen and Hoareau, 2003; Cohen et al., 2002). By focusing on the application of proof concepts, new and small ventures can provide individuals with incentives for exploring the application of specific technologies, hence they provide a favorable environment to develop innovations based on ideas close to the experience and knowledge of their founder/employees, them being market, scientific or individual serendipitous knowledge sources that lead also to great technological advances (Klepper, 2001).

On the other hand, small and young firms lack complementary assets, including facilities and capacity to produce, test and market new products, and a managerial system focused on exploitation, which are often required to bring novel technological ideas into the market (Teece, 1986; Rothaermel, 2001). The selection and the development of innovative ideas based on scientific knowledge may require strong organizational incentives towards exploitation that are not available in small and young firms.

In sum, the organizational flexibility and lack of strong financial incentives associated with the loss of an established customer basis make small and young firms an environment that reinforces the effect of knowledge sources on the nature innovation (Bulgerman, 1994; Riggs and von Hippel, 1994). Instead, the organizational, financial and market rigidities of large firms create incentives for selecting out exploratory ideas or for turning them into market exploitation innovations, i.e. for eroding the imprinting effect of knowledge sources on the nature of innovation (Bulgerman, 1994; Riggs and von Hippel, 1994).

Based on the above discussion, we hypothesize the following:

H2: The imprinting effect of ideas on innovative outcome will be stronger for smaller firms than for large firms.

3. Methodology and Data

3.1. Methodology

We want to investigate how technological exploratory and market exploitative innovations are effected by idea origin and how this effect is mediated by organizational selection as outlined in the previous sections. We hypothesized that different knowledge sources used in the idea-generation process and organizational environments in which development process took place enable different types of innovations, and their interaction attenuate or reinforce individual influence.

Technological exploratory and market exploitative innovations are dichotomous variables which are not mutually exclusive and may be correlated. In order to estimate simultaneously the propensity of both types of innovation we use bivariate probit maximum likelihood estimation method, which estimates the probability of each type of innovation as a function of a set of explanatory variables, including the knowledge sources for idea generation and the interaction of these imprints, with the organizational environment in which the innovation was developed. We further include a set of control variables, including technology class and financing of the development process.

The bivariate probit model can be written as:

$$y_1^* = X\beta_1 + \varepsilon_1 \, with \, y_1 = D(y_1^* > 0) \quad (1)$$
$$y_2^* = X\beta_2 + \varepsilon_2 \, with \, y_2 = D(y_2^* > 0) \quad (2)$$

where y1 and y2 represent the two types of innovations and X is a set of explanatory variables including the idea sources and their interactions with organizational structure. The log-likelihood function is then given by:

$$lnL = \sum ln\Phi_2(q_1 X_i \beta_1, q_2 X_i \beta_2; \rho^*) \quad (3)$$

where $q_m = 2y_m - 1$ and $\rho^* = q_1 q_2 \rho$. $\Phi_2()$ is the joint normal distribution function of order 2. If $\rho = 0$ then the expression for the likelihood function is equal to the sum of the likelihoods of the two univariate probit models. If this condition is not met it is necessary to estimate the two equations simultaneously using Maximum Likelihood Method. The standard errors are robust and clustered at the level of the inventor, in order to control for imprints that individual experience and competences that could influence the outcomes of the innovative process.

3.2. Data

We examine the processes behind the development of two innovations: market exploitative innovations (innovation with greatest market value) and technological exploratory innovations (innovation that made greatest use of university knowledge), using data collected from a sample of inventors. The data comes from an original survey (PIEMINV) of industrial inventors targeted at investigating the generation and development processes and the outcome of two innovation processes, which to an extent also allow us to control for individual imprints on the innovation development process (Felin and Hesterly, 2007; Foss, 1996).

The PIEMINV survey questionnaire was sent to the population of inventors with an address in Piedmont (a region in Northern Italy) that had applied for at least one EPO patent during the period 1998-2005 (3922 patents and 3,027 inventors were identified). Addresses were collected from EPO patent applications and updated using telephone directory information and by calling patent firm applicants. After cleaning and confirming address data we sent out 2916 questionnaires by email and post between autumn 2009 and spring 2010. We obtained 901 valid responses (response rate 31%). 391 questionnaires could not be delivered resulting in an effective response rate of 36% (see Bodas Freitas et al., 2014).

The questionnaire was designed to investigate various aspects of the inventive process of inventors in Piedmont, and to enable quantitative measurement of the innovative process and their outcome, and the university's contribution to their innovation process. The survey was targeted at inventors (R&D employees) who are generally much better informed about the development processes behind individual innovations than managers, who are usually the target of innovation surveys. The survey thus has the benefit of being able to evaluate the inventive processes behind different innovations by different inventors inside the same firm, instead of firm-level analyses that assume firm specific innovation strategies to be most important.

For this study we use information collected in the second section of the questionnaire that asked information about the processes of idea-generation and development behind two specific innovations: (1) the innovation with the highest contribution from scientific knowledge sources, and (2) the innovation with the highest economic impact. In our analysis these two innovations represent proxies for technological exploratory innovations and market exploitative innovations respectively. The survey is thus also able to evaluate the innovation processes behind two distinct innovations by the same inventor, which allows overcoming difficulties of comparing innovations with different technological and market focus across inventors with different competences and experiences. In other words, it permits to control for individual imprints on the innovation development process.

This part of the questionnaire was only answered by inventors that have reportedly benefitted from university knowledge for at least one of their innovations, so that we could have answers relative to both types of innovations. We are aware that this results in having selected the most technological competent industrial inventors to answer.[1] In our sample 293 inventors reported some university contribution, which represents 33% of the total sample; and 220 inventors were able to supply information on two specific innovations (24%). Respondents could choose the same innovation in both questions if their innovation with greatest technological exploratory value or focus coincided with the innovation with greatest market value. In 66 cases the innovation with the highest contribution from scientific knowledge sources also represented the innovation with the highest economic impact. This represents 30% of inventors.

Dependent variables

The survey asked about the inventive process of the innovation that most benefited from scientific knowledge and classed these as innovations that lead to scientific and technological advances, i.e. technological exploratory innovations. The survey further asked about market exploitative innovations, i.e. innovations with the greatest market value. Our dependent variables are dichotomous variables. Technological exploratory innovation takes the value 1 if the innovation is the one that most benefitted from scientific knowledge. Market exploitative innovation takes the value 1 if the innovation refers to the one that had the highest economic impact. These two innovations are not exclusive categories, since some innovations were both considered as technological exploratory and market exploitative innovations.

Respondents were asked if they agreed or disagreed with a number of statements relating to technological exploratory innovations. Table 1 gives an overview over statements and responses. It shows that as previously hypothesized, technological exploratory innovations enable new lines of research but that at the same time they face problems of applicability and uncertainty. Breach of secrecy is only a minor problem, however.

[1] This is confirmed if we estimate a selection model. Those inventors are higher educated and have produced invention of wider applicability than their colleagues (generality index, Trajtenberg et al., 1997).

[Insert Table 1 here]

Already Table 1 suggests that a large percentage of technological exploratory innovations can coincide with market exploitative innovations. Also, 30% of respondents indeed stated that their technological exploratory innovation was also their innovation with the highest market returns.

Independent variables

The first set of independent variables capture information on the process of idea-generation. The survey asked respondents about the origin of the idea leading to the two innovations. Based on this information, we build variables that capture information on the knowledge sources at the origin of the projects. *Internal* source takes the value 1 if the project had at its origin knowledge that was developed by the internal R&D lab. *Market activities* takes the value 1 if the project's original idea was based on information from the interaction with other market actors. *Scientific* source takes the value 1 if the project's original idea was based on university knowledge or knowledge developed in collaboration with universities and PROs. *Individual* knowledge sources take the value 1 if the project's original idea was based on serendipity or on knowledge developed during the inventor's training or experience.

Table 2 shows that the majority of inventors received their ideas from firm internal activities. In line with our expectations, ideas coming from university sources or through serendipity seem to be closer associated to technological exploratory innovations.

[Insert Table 2 here]

The second set of independent variables capture information on the organizational processes of idea-development. The survey asked respondents about the organization where they were employed at the time the innovation was being developed. Respondents are asked if they were employed by a large *established firm*, if they were *self-employed* or if they were working in a *public research organization* (university, hospital, public institute). We proxy new or small ventures with self-employment. Variables capturing the linear interaction between each knowledge source at origin of the innovation and each organizational environment were used. In order to isolate the organizational effects, we also include interaction with the variable public research organization.

Table 3 shows the responses with regard to the two types of innovations. There is little difference between the organizational structures for technological and market innovations.

[Insert Table 3 here]

Control variables

The sources of project development financing could also influence the development efforts and the selection of preliminary results during the development process. Hence, the forms of financing are used as a control variable in some of the regressions. While the majority of projects were financed internally, 19% of innovations were financed through public research grants. We further include technology classes of patents filed by each of the inventors to our regressions. The most common technology class is electronics with 29% of inventors followed by machinery with 25% and instruments and chemistry with 13% and 12% respectively.[2] In addition we add personal control variables including age in 2010 (the time of the survey), whether the inventor has a university degree, the gender of the inventor and the number of EPO patents he or she filed between 1998 and 2005.

[2] Patents were classified according to the DT7/OST reclassification of IPC (OST, 2004). The remaining classes are pharmaceuticals with 3%, process engineering with 10% and others with 8%.

Table 4 provides the means, standard deviations and mean differences between the two innovations; and Table 5 reports the correlations matrix for all study variables. Some inventors were unable to answer all the questions for both innovation types. Thus, due to missing answers the final sample considered in this analysis consists of 184 inventors reporting on 286 innovations. Of these, 121 are technological exploratory, 107 are market exploitative and 58 represent a technological exploratory innovation that is also the one with greatest market value. Table 4 shows that we find significant mean differences between market and technological breakthroughs. A significantly larger share of market exploitative innovations has been financed through firm internal resources, while technological exploratory benefited more from public financing and formal university contacts. Technological exploratory innovations are further closer associated with project ideas coming from public research than market breakthroughs.

[Insert Table 4 and Table 5 here]

4. Results

Main results

Table 6 presents the results of the bivariate probit. Marginal effects are reported. The ancillary parameter rho, that measures the correlation of the residuals from the two models, shows that the two equations are strongly negatively associated (rho=-1). Model 1 is the baseline model with controls only. Model 2 adds the main effects of knowledge sources and Model 3 adds main effects of organizational environment and the interaction between the knowledge sources and organizational environment.

[Insert Table 6 here]

Results show that market exploitative innovations are less likely to rely on scientific and individual knowledge sources than on internal knowledge or market sources. Hence, in line with our expectations set in H1 that internal and market sources, which provide knowledge closer to the firms' activities than scientific or individual sources, are more likely to lead to market exploitative innovations.

None of the linear independent effects of the organizational environment, the mediation effects, are significant. At the interaction, idea-generation and idea-selection behave as follows: Ideas coming from scientific or individual sources and developed inside established firms are less likely to lead to market exploitative innovations than those based on ideas from firm internal and market sources. This result corroborates H2 that states original ideas are more likely to be eroded in established firms than in small or young firms. Market knowledge sources, which are close to the industry, and individual experience and knowledge developed at public research organizations or small or new firms are more likely to lead to market exploitative innovations than the base category of internal sources developed within large established firms. We have further seen that individual serendipitous knowledge sources are also more likely to lead to market exploitative innovations if the project is developed in a small or young venture rather than within large established firms.

Technological exploratory innovations on the other hand are more likely to be achieved if scientific knowledge sources rather than internal, market or individual sources are used, especially if the project is developed in a small or new venture rather than in a long established large firm. These results provide empirical corroboration for H2 stating that original innovation ideas are likely to be reinforced by small or young firms than in large incumbent firms.

As to what regards our control variables, invention development processes that were financed through public grants and developed in direct collaboration with universities are less likely to result in market exploitative innovations. The technological field controls are all insignificant as is age, education and patent output. Women are more likely to develop technological exploratory innovations than men.

Marginal effects on joint probabilities

Table 7 shows the marginal effects on the joint probabilities of an innovation that is technological exploratory as well as market exploitative (Pr(market=1,tech=1)), as well as for an innovation of market or technological value in the absence of the respective other (Pr(market=1,tech=0)/ Pr(market=0,tech=1)). Column one shows that the joint probabilities of an innovation to be of market exploitative value alone decreases if scientific knowledge sources are at its origin. This confirms H1. If scientific sources are developed in new firms, they are least likely to result in market exploitative innovation, providing support for H2.

In contrast, the joint probability of an innovation being technological exploratory but not of market value increases if ideas were formed in a scientific environment or serendipitously by the inventor, confirming H1. It further increases if scientific ideas were developed in a new venture, supporting H2, but decreases for ideas from market sources that were developed in small firms or in a public environment as compared to large firms, providing some additional evidence for H2.

The joint probability of a technological exploratory as well as market exploitative innovation (column 3) decreases significantly if ideas from scientific environments are developed in a newly formed company. Thus, while such innovations may be exploratory in nature they are not successfully market exploitative. This is in line with H2. Instead market ideas developed in new firms are more successful than if they were developed elsewhere.

[Insert Table 7 here]

Overall, these results corroborate our expectations that the origin of ideas influence the nature of the project's innovative outputs and that these are mediated by the organizational environment in which ideas are selected and developed.

5. Conclusions and Discussion

This study aimed at examining how *origin* and *selection* of the innovation behave at the intersection. Specifically, we focus on how the strategy of the organization where the idea is developed (i.e. the organizational environment in which the project is developed) reinforces or erodes the imprinting from idea generation (i.e. the knowledge sources at the project's origin) on the nature of innovation outcomes. We use data from a survey to Italian inventors on the process of innovation development of two innovations: market exploitative innovation (greatest market value) and the technological exploratory innovation (greatest use of university knowledge), which to some extent permits to control for individual imprints on the innovation development process.

Results show that internal R&D and market sources providing knowledge closer to the firm' core activities than scientific or individual serendipitous sources, are more likely to lead to market exploitative innovations. This confirms our expectations on the linear independent effect of idea-generation imprints on the nature of the innovation. This is also in line with research that has shown that the origin of technological knowledge influence innovation output (Phene et al., 2006).

Results also confirm that the organizational and managerial environment in which the selection and development of innovative ideas occurs moderates the imprinting effect of the innovation origin, for example by influencing the selection through the innovation objectives of the organization and the availability of a specific mix of resources and assets. Specifically, we find that individual serendipitous knowledge sources and firm internal R&D and market sources are more likely to lead to market exploitative innovations if the project is developed in a small or young venture and within large established firms, respectively. Individual serendipitous knowledge sources distant from the organizational capabilities of established firms but close to individual experience of founders/employees can be pursued and reinforced in small or young ventures, where customer basis and complementary assets provide a lesser bias to develop market breakthroughs from personal promising ideas. Market knowledge sources are also more likely to lead to market exploitative innovation if developed in small firms. Scientific knowledge sources are instead respectively less likely to lead to market exploitative innovation if developed in small firms. In sum, sole and small venture organizational environments seem to reinforce the effect of knowledge sources on innovation nature, while large established firms seem to oppose the imprinting effect of knowledge sources not developed internally by the firm. In other words selection environments characterized by organizational, financial and market rigidities are more likely to attenuate the imprinting effect of knowledge sources that are distant from the firms' capabilities and managerial systems.

This study is not without some limitations. Addressing these limitations could open up several avenues for future research. First, our result might partly reflect our research design that compares two different types of innovations as provided by industrial researchers rather than drawing on a sample of innovations in one technological field. Further, information on the idea generation and development process of these inventions is limited to the questions posed on the questionnaire. Thus, further research is needed to examine whether these findings are corroborated when comparing market exploitative and technology exploratory innovations selected on the basis of their market return or novelty. Qualitative research based on interviews and case studies could help provide rich insights on organizational and knowledge sources of the different inventions. Second, our data source is a single country and region, Piedmont region in Italy. While we have no reason to believe that these two innovations are of different likelihood or meanings in this region, it would be interesting to analyze the extent to which these results can be generalized to other countries and regions given that cross-country and cross-regional differences may exist between specific academic and industrial specialization. The examination of the generalizability of our results relying on different research methods and addressing different national and regional contexts would provide further insights on this issue. Finally, our paper provides no evidence on whether exploitation or exploration is the preferred innovation outcome.

In conclusion, our study was a first attempt to open up the black box of how knowledge sources feeding the idea-generation process influence the nature of innovations developed and how these imprints from the idea-generation process interact with the organizational environment in which the project is being developed.

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Tables

Table 1: Agreement to statements relating to technological exploratory innovations

Statement	Agree	Do not agree
Was at an earlier stage of development	28.64%	25.45%
Has the highest number of potential uses	29.09%	19.09%
Has opened up new research lines in your company	42.73%	20.45%
It has been difficult to it apply to new product development	34.09%	24.55%
Has not led to a market innovation	20.00%	33.18%
Could not be patented because knowledge had previously been published/leaked/disputed	4.55%	55.91%

Note: “Don’t know” was the third option available.

Table 2: Idea sources for technological exploratory and market exploitative innovations

Idea Sources	Technological	Market	Technological and Market
Internal	50.36%	62.79%	55.38%
Market activities	16.70%	23.26%	15.38%
Scientific	21.09%	6.98%	20.00%
Individual	10.95%	6.98%	9.23%
# of Respondents	137	129	65

Table 3: Organizational environment for technological exploratory and market exploitative innovations

Organization	Technological	Market	Technological and Market
Established firm	80.25%	82.67%	79.71%
Self-employed	10.19%	10.00%	5.80%
PRO/University	9.55%	7.33%	14.49%
# of Respondents	157	150	69

Table 4: Variables used in regressions (286 observations)

	All		Market=1 Tech=0		Market=0 Tech=1		Market=1 Tech=1		
	mean	sd	mean	sd	mean	sd	mean	sd	Mean difference market vs. tech
Dependent Variables									
Market exploitative	0.58	0.49	1.00	0.00	0.00	0.00	1.00	0.00	
Technological exploratory	0.63	0.48	0.00	0.00	1.00	0.00	1.00	0.00	
Organizational environment									
Established company (reference)	0.80	0.40	0.82	0.38	0.80	0.40	0.78	0.42	ns
Self-employed	0.08	0.28	0.09	0.29	0.08	0.28	0.07	0.26	ns
PRO/University	0.11	0.32	0.08	0.28	0.12	0.32	0.16	0.37	ns
Idea sources									
Firm internal R&D (reference)	0.56	0.50	0.65	0.48	0.50	0.50	0.52	0.50	+**
Market activities	0.19	0.39	0.22	0.42	0.16	0.37	0.17	0.38	ns
Scientific	0.16	0.37	0.07	0.25	0.23	0.42	0.21	0.41	- ***
Individual	0.09	0.29	0.06	0.23	0.12	0.32	0.10	0.31	ns
Project financing									
Firm financing (reference)	0.87	0.34	0.88	0.33	0.83	0.38	0.93	0.26	ns
Public financing	0.19	0.39	0.17	0.38	0.23	0.42	0.12	0.33	-*
Joint financing	0.05	0.22	0.05	0.21	0.06	0.23	0.05	0.22	ns

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Correlation matrix of regression variables (286 observations)

	1	2	3	4	5	6	7	8	9
1 Market exploitative	1.000								
2 Technological exploratory	-0.662***	1.000							
Project financing									
3 Public financing	-0.102*	0.034	1.000						
4 Joint financing	-0.021	0.020	0.493***	1.000					
Organizational environment									
5 Self-employed	0.004	-0.027	-0.079	-0.071	1.000				
6 PRO/Univ	-0.010	0.068	0.316***	-0.034	-0.107*	1.000			
Idea source									
7 Scientific	-0.155***	0.206***	0.128**	-0.062	-0.032	0.202***	1.000		
8 Individual	-0.074	0.094	0.100*	0.089	0.080	0.389***	-0.140**	1.000	
9 Market activities	0.062	-0.078	-0.089	-0.072	-0.047	-0.084	-0.211***	-0.151**	1.000

* $p < 0.05$, ** $p < 0.01$

Table 6: Bivariate probit regression

	Model 1		Model 2		Model 3	
	Market	Technological	Market	Technological	Market	Technological
Idea sources						
Firm internal R&D			reference			
Market activities			0.009	-0.015	-0.013	-0.019
			(0.057)	(0.052)	(0.058)	(0.056)
Scientific			-0.217***	0.339***	-0.194**	0.386***
			(0.071)	(0.073)	(0.083)	(0.096)
Individual			-0.111	0.199***	-0.278*	0.197
			(0.071)	(0.076)	(0.143)	(0.160)
Organizational environment						
Established company			reference			
Self-employed					-0.060	-0.065
					(0.077)	(0.070)
PRO/University					0.165	-0.048
					(0.258)	(0.225)
Interactions						
Market*Self-employed					2.609***	0.120
					(0.132)	(0.252)
Market*PRO/Univ					2.739***	-0.124
					(0.268)	(0.357)
Scientific*Self-empl					-2.629***	2.339***
					(0.140)	(0.148)
Scientific*PRO/Univ					-0.067	-0.217
					(0.294)	(0.280)
Individual*Self-empl					0.506**	-0.198
					(0.242)	(0.232)
Individual*PRO/Univ					-0.011	0.177
					(0.328)	(0.317)
Project financing						
Firm financing			reference			
Public financing	-0.157**	0.021	-0.117*	-0.041	-0.135*	-0.032
	(0.067)	(0.070)	(0.068)	(0.069)	(0.072)	(0.073)
Joint financing	0.116	-0.007	0.055	0.114	0.078	0.085
	(0.095)	(0.096)	(0.100)	(0.106)	(0.103)	(0.110)
Controls						
Age	0.000	-0.002	-0.002	0.000	-0.003	0.001
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
Higher Education	-0.024	-0.006	-0.017	-0.004	-0.042	-0.006
	(0.040)	(0.041)	(0.045)	(0.042)	(0.048)	(0.047)
Female	0.122**	0.086	0.108*	0.092	0.062	0.137*
	(0.062)	(0.061)	(0.064)	(0.064)	(0.069)	(0.073)
Patent number	-0.002	-0.004	-0.001	-0.005	-0.000	-0.003
	0.000	-0.002	-0.002	0.000	-0.003	0.001
Technology class dummies	YES	YES	YES	YES	YES	YES
N	306		299		286	
N_clust	187		185		184	
ll	-313.418		-297.167		-276.633	
ρ	-1		-1		-1	
$LR(H_0: \rho=0)$	0.045		1.091		9.001***	

Robust standard errors in parentheses. Errors are clustered at the individual inventor level. Average marginal effects are reported. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Marginal effects on joint probabilities

	Pr(Market=1,Tech=0)	*Pr(Market=0,Tech=1)*	*Pr(Market=1,Tech=1)*
Idea sources			
Firm internal R&D	Reference	Reference	Reference
Market activities	0.019	0.014	-0.032
	(0.059)	(0.061)	(0.058)
Scientific	-0.316***	0.209**	0.0107
	(0.057)	(0.091)	(0.093)
Individual	-0.180	0.297**	-0.117
	(0.124)	(0.145)	(0.111)
Organizational environment			
Established company	Reference	Reference	Reference
Self-employed	0.069	0.065	-0.134
	(0.077)	(0.084)	(0.088)
PRO/University	-0.084	-0.163	0.111
	(0.102)	(0.233)	(0.247)
Interactions			
Market*Self-employed	-0.115	-0.426***	0.541**
	(0.215)	(0.117)	(0.216)
Market*PRO/Univ	0.137	-0.427***	0.291
	(0.405)	(0.018)	(0.403)
Scientific*Self-empl	-0.365***	0.632***	-0.267***
	(0.019)	(0.017)	(0.027)
Scientific*PRO/Univ	0.205	-0.037	-0.151
	(0.313)	(0.304)	(0.301)
Individual*Self-empl	0.220	-0.353***	0.133
	(0.262)	(0.074)	(0.246)
Individual*PRO/Univ	-0.162	-0.011	0.151
	(0.245)	(0.350)	(0.306)
Project financing			
Firm financing	Reference	Reference	Reference
Public financing	0.034	0.146*	-0.179***
	(0.077)	(0.079)	(0.052)
Joint financing	-0.084	-0.080	0.163
	(0.102)	(0.102)	(0.111)
Controls			
Age	-0.002	-0.004	-0.002
	(0.002)	(0.002)	(0.003)
Higher Education	-0.007	-0.044	-0.051
	(0.049)	(0.050)	(0.066)
Female	-0.132**	0.064	0.196*
	(0.064)	(0.070)	(0.116)
Patent number	-0.003	-0.000	-0.003
	(0.005)	(0.009)	(0.009)

Robust standard errors in parentheses. Errors are clustered at the individual inventor level. Technology class dummies are included in all regressions. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$