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Collective vs. expert rationality for evaluation of new technologies in crowdsourcing initiatives

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Abstract

As firms open the innovation process to the contribution of large groups of users and experts, the process of idea generation benefits from an increased volume and variety of inputs. This implies also an escalation of the complexity of idea screening and selection. Idea markets assist managers in this task by offering a collective assessment of the quality of ideas. This paper investigates to what extent the judgement of markets and experts overlaps. We take as our empirical case an internal idea competition launched by a multinational company operating in a science-based industry. The study shows that experts? appraisal is substantially aligned with the outcome of the idea market. However, while inventions of senior employees tend to be better received by experts, the market appreciates more ideas for which the inventor provides rich information. Inventions that attract participants? comments tend to be better rewarded in both evaluation systems.

Jelcodes:O31,O32

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Introduction

Shortening of product life cycles and exacerbation of competitive pressure in many industries are challenging firms at increasing the pace of product innovation. The entrenchment of "open innovation" as a managerial practice combined with the exploitation of information technologies are opening unprecedented opportunities for firm to manage distributed R&D projects (Amaral et al. 2011; Bardhan et al. 2012). Online idea competitions are gaining recognition as a tool to activate co-creation processes that bring together large and dispersed communities of users and external experts (Piller, Walcher, 2006; Ebner et al., 2009; Bayus, 2013). However, they are also powerful integration mechanism in R&D organizations that need to bring together knowledge developed by many employees located in multiple sites: under-utilization of *internal* cognitive resources is a major issue in big companies (van Dijk and van den Ende, 2002). Online idea competitions, and particularly those based on "idea markets", enable firms to recombine their cognitive resource and to improve their ability to generate new inventions and to provide support to their management in the screening and selection process (Dos Santos, Spann, 2011).

The use of idea competitions within an organization is under-researched. Notable exceptions are the works by LaComb, Barnett, and Pan (2007), Chen et al. (2010), Spears et al. (2010), Dos Santos and Spann (2011), and Soukhoroukova, Spann, and Skiera (2012). Still, there is little evidence of how the interplay between the *collective* rationality of an idea market and the *expert* rationality of the R&D management. Indeed, when adopting an idea competition to boost the innovation process, the R&D management does not renounce to its responsibility regarding selection of ideas: actually, the market system supports – not replaces – decision-making in the R&D function.

It is then important to understand what kind of information the market uses in the screening process, and whether these information are specific to the idea market, or are already available to the R&D management. For a company that is evaluating the returns of an investment in an online idea competition and its incremental effect compared to the traditional R&D process, it is relevant to ascertain to what extent idea markets interpret existing information similarly to experts, and to what extent they offer alternative evaluation.

We address these issues by analysing an idea competition project deployed by the Danish multinational company Novozymes. The company launched an internal idea generation contest that was aimed at identifying an invention with high market potential in the field of industrial enzymes. An idea market was designed with the purpose of stimulating idea generation and selection; a peculiarity of this project was the possibility for participants to provide comments on ideas. The contest was opened to a selected group of employees belonging to 8 research centres in 6 countries, and was structured in order to allow frequent steering and intervention by the R&D management.

This empirical setting appears particularly suitable to study how inventors' existing reputation and information generated by different sources affect the screening and selection process.

This paper is one of the first empirical contributions on similarities and differences between "expert" vis-à-vis "collective" rationality in a complex problem solving setting such as idea generation – a phenomenon that has been theorized only recently (Afuah and Tucci 2012; Poetz and Schreier, 2012; Hienerth and Riar, 2013).

Furthermore, it illustrates underexplored possibilities of application of an increasingly diffused tool for management of innovation, such as idea markets.

The rest of the paper is structured as follows: in Section 2 we develop the theoretical framework and a series of propositions; in Section 3 we present the methodology of the study, while in Section 4 we illustrate the results. The paper is concluded by the managerial implications and the perspectives for future research.

Theory

Improving idea generation by extending the pool of inventors

In a behavioural perspective, decision-making at individual, team and organization level is subject to limitedness of available information and to limitations in agents' cognitive resources, time and attention (March & Simon, 1958; Cyert & March, 1963). Bounded rationality affects the whole process of new product development: the impossibility to completely understand the technological and market environmental changes drives actors to reduce complexity by specializing in specific domains (Dequech, 2001; Krishnan & Ulrich, 2001). This means that actors constrain their search for solution to innovation problems to domains that are cognitively proximate to their existing scientific knowledge and technological expertise (Stuart and Podolny, 1996; Tripsas and Gavetti, 2000), and adopt heuristics to prioritize their attention among projects (Ocasio, 1997; Bentzen et al., 2011).

In line with a consolidated approach in the literature that conceives innovation as a process of combination and integration of knowledge (Fagerberg, 2005; Fleming and Sorenson, 2004; Rothaermel and Alexandre, 2009), one of the priorities of R&D management is to broaden volume and variety of the inputs (Neyer et al., 2009). In order to overcome the limitations of local search in this regard, companies are opening to actors and sources of knowledge that lie outside their organizational boundaries (Laursen, 2012).

Companies have introduced "innovation contests" to step up the new product development process by utilizing ideas and knowledge made available by external actors (Adamczyk et al. 2013). Typically, innovation contests are structured as follows (Flynn et al. 2003; Toubia, 2005; Piller, Walker, 2006; Terwiesch, Xu, 2008; Terwiesch, Ulrich, 2009; Ebner et al. 2009; Fuller, 2010; Morgan, Wang, 2010; Boudreau, Lacetera, & Lakhani, 2011; Erat, Krishnan, 2012). The organizing company sets a goal that may be either the solution of a specific technical or business problem or the identification of opportunities for opening new markets or reorienting its strategy. Participants provide ideas or solutions to the challenge within a definite timeframe. Participation may be opened

to the general public, to current consumers, to lead users or to selected participants. Once the solicitation for ideas has ended, a committee of internal experts (e.g. managers, engineers, scientists, or designers) filters the proposals; also participants may be involved in the filtering task. The goal of this stage is to rank contributions in order of priority to the organization. This stage is crucial, as it involves decisions of which ideas to accept or reject. It is important that the company arranges mechanisms to retain ideas that do not provide solutions to the stated problem, but offer solutions to problems not yet identified. At the end of this stage, the company awards the authors of the best ideas. Finally, the selected ideas undergo a maturation process that improves their technical and commercial feasibility.

Afuah and Tucci (2012) identify a series of conditions under which the involvement of a broad community improves the search process, compared to alternative solutions such as internal problem solving and outsourcing to a specific contractor: the existence of an efficient IT infrastructure; the possibility to convey the need to the participants; the necessity to deviate from the existing technological trajectories and to rely on complementary knowledge and technologies; the level and heterogeneity of the knowledge of participants: as participants' rationality is also bounded, they search for possible solutions in proximity of their knowledge base; for this reason, broad and diversified communities are more likely to provide solutions to a given problem; the extent to which the company can efficiently evaluate the solutions offered by the crowd, not only from a technical point of view but also in terms of fit with competencies, feasibility, and expected return on investment (Dos Santos, Spann, 2011).

Empirical evidence reveals that contributions of peripheral actors advance the search process by improving the variety of approaches and perspectives to the problem thus broadening the technological trajectories, while expert teams tend to generate more homogeneous solutions (Girotra et al., 2010; Jeppesen and Lakhani, 2010; Kornish and Ulrich, 2011). Recently, a comparative study has contrasted new product concepts proposed by potential customers to those elaborated by internal experts, showing that an company evaluation team acknowledged higher novelty and customer feasibility to the former group (Poetz, Schreier, 2012).

R&D organizations of large, multisite companies represent a different yet particularly interesting setting for application of innovation contests. Members of R&D organizations are skilled professionals who are able to contribute to problem solving. However, this cognitive resource is often not adequately exploited because of difficulties in communication and circulation of ideas, and poorly designed, bureaucratic idea generation systems (Burt, 2004; van Dijk, van den Ende, 2002). Gamification of idea generation incentivizes scientists to engage in the creative process, better than routinized ideation techniques; the idea generation platform represents a channel of communication that permit ideas to spread in the organization, facilitating cross-fertilization with ideas generated in distant sites of the organization (Piller, Walker, 2006; Bardhan et al. 2012; Santos, Spann, 2011). In other words, by mobilizing complementary cognitive inputs, these tools link together local search patterns that are pursued in distant sites of the organization (Afuah, Tucci, 2012).

Studies on "open" innovation contests have critically pointed out that innovation contests are effective in raising large amounts of ideas, but very few of them are valuable contributions to problem solving. This is due both to the fact that the individual participant has little incentive to commit a significant amount of intellectual resources (Terwiesch, Xu, 2008; Di Gangi et al. 2010; Magnusson, 2010), and that users tend to be more tied to the current technological solutions and thus are less able to envision ground-breaking technologies and applications (Christensen and Bower, 1996; Schulze and Hoegl, 2008). Indeed, innovation contests generally privilege the potential variety of technological options rather then their quality. As a consequence, the screening process is very demanding in terms of managerial attention (Mortara et al. 2013). This implies that companies should consider the potential trade-offs between variety of ideas, quality of ideas and managerial attention when designing an innovation contest.

Improving the efficiency of idea screening with preference markets

Typically company experts are in charge of screening and ranking new product ideas. Also this task can be improved by relying on a collective intelligence. Preference markets permit the integration of the idea generation and idea evaluation stages (Slamka et al. 2012). Participants in a preference market submit their own ideas and assess their peers' ideas by means of a trading mechanism. Each idea or product concept is represented by a security and participants trade these securities using play money. Assuming that trading decisions reflect participants' evaluation of their quality, it is possible to rank ideas by using information generated in the market – e.g. volume-weighted average trading prices or the last fixed price. Traders are motivated to reveal their actual preferences towards the ideas by setting a reward that is based on the value of their virtual assets – i.e. portfolio of shares and play money. The functioning of preference markets rests on the notion of "crowdsourcing" according to which aggregation of a large amount individual opinions, although biased, is more effective than the judgement of a small group of experts (Surowiecki, 2004). Aggregation of information provided by a pool of independent participants is expected to reveal the quality of ideas. However, it is not possible to compare the outcomes of a preference market with the "real" value of the ideas: only a small subset of ideas presented in the market are further developed and become products; and also the revenues generated by those ideas can be known only years after the launch of the products. For these reason, external validation of the outcomes of a preference market can not be offered by the actual economic performance of products, but rather by panels of experts (Slamka et al. 2012).

By relying on a collective intelligence, companies have the opportunity to reduce the complexity of the evaluation task, which escalates with the volume of submitted ideas (Soukhoroukova et al. 2012). Anyhow, experts' judgement is still utilized to determine the final ranking of ideas in multi-stage competitions. This provision helps mitigating the possibility that the outcomes of peer assessment are influenced by personal rivalries or other kinds of social dynamics; indeed, the efficacy of this evaluation method is strongly dependent on the fairness and expertise of the participants (Lampel et al. 2012).

The issue of evaluation is one of the open problems in the field of research on innovation contests (Adamczyk et al. 2013). A recent work by Hienerth and Riar (2013) has conceptualized how

crowds and expert teams differ in evaluating novel product concepts and technologies. The authors offer a framework to appreciate how the nature of the evaluator affects the quality of the evaluation, depending on four contingency dimensions: the maturity and the volume of ideas under scrutiny as well as the commitment and the expertise of evaluators. The authors suggest that the evaluation task is more challenging in the early stages of the development process, as ideas are more prone to be transformed and refined as the company acquires complementary knowledge of the technology and potential markets (Crawford, Di Benedetto, 2006); in these cases, experts' knowledge is better suited to evaluate early ideas, because of their attitude to interpret emerging trends. The evaluation process benefits from expert knowledge when the number of ideas to assess is small; in such a case, experts have the possibility to thoroughly screen each proposal. However, bounded rationality, cognitive specialization and limited attention preclude an in depth analysis of large amounts of ideas; in such a case, it is likely to find in the crowd at least some people with the necessary competencies to evaluate ideas referring to heterogeneous domains. So, the appropriateness of the evaluation method depends on the number of ideas under scrutiny. It is important to stress that level and area of specialization are quite clearly defined and institutionalized in teams of experts, the specific interests, skills, and expertise of members of a crowd can freely emerge through interaction in the evaluation process. Finally, the quality of evaluation is dependent also on availability of evaluators to invest their time and intellectual resources in the process; while for experts such commitment is part of their contractual obligation towards the company, while a crowd need to be adequately incentivized.

Comparing decision-making of experts and crowds

In light of the above considerations, it appears particularly interesting to investigate how experts' and crowds' evaluation differ in idea generation contests that address relatively small populations of skilled participants and include an idea market as screening mechanism. This kind of innovation contests present a high degree of technical uncertainty – as they take place at the fuzzy front end of innovation process – but reduce the complexity of the decision-making process by reducing the number of ideas under scrutiny and the presence of technologically insignificant contributions. A critical issue regarding decision making in this context concerns the sources of information that the crowd and the expert utilize: what features of innovation projects do they take into consideration? To what extent their selection criteria overlap?

We argue that evaluators of an innovation project consider information on both the invention and on its inventor.

The design of an innovation contest determines what kind of information on proposals is produced and disclosed during the campaign. Traditionally, inventors provide information by describing their ideas at submission; recent innovation contests include commenting platforms that enable a continuous, multi-directional flux of information, involving the inventor and the participants. This allows information to be generated also during the campaign. We expect that evaluators direct their attention towards proposals for which rich and complete information is made available by its inventor, because it permits a thorough exam of its strengths and weaknesses. Furthermore, interaction between inventors and participants in the market through a commenting platform allows

the opportunity of replying to criticism and to better refine their ideas. However, the notion of bounded rationality suggests that information overflow impedes effective decision-making thus implying a decreasing return of the utility of information (Calantone and Townsend, 2010; Citroen 2011; Cousins et al. 2012). For these reasons, we formulate *Proposition-1* stating that *a collective decision-maker focuses its attention on ideas for which a moderate amount of information is available.*

Previous experience in patenting, scientific publishing and proposal of inventions is an objective indicator that an employee possesses creative capabilities (Subramaniam, Youndt, 2005; Audia, Goncalo, 2007; Subramanian et al. 2013). Such information is particularly relevant under bounded rationality conditions, in which decision-makers put into place complexity-reduction mechanisms. Reputation is one of these mechanisms, by which evaluators will direct their limited attention and cognitive resources on ideas submitted by employees who have already succeeded in the invention process, under the assumption that their higher creativity will lead to more valuable inventions. We then formulate *Proposition-2* stating that *a collective decision-maker focuses its attention on ideas submitted by employees with inventing experience*.

The ability to generate valuable ideas depends not only on technical skill but also on the ability to interpret a company's strategy and priorities. This skill is idiosyncratic to the organization in which an individual operates. As employees build this skill by means of a process of on-the-job learning, we argue a positive effect of the years spent in the company on their ability to generate inventions. In fact, seniority has a similar reputational effect as the one of experience in innovating, leading evaluators – and particularly experts who are senior members in the organization – to privilege the examination of ideas by senior employees. However, we acknowledge that inertial processes may dampen creativity as employees accumulate experience in the same organization: an excess of familiarity and comfort with a company's routines impedes the generation of unconventional ideas (Aagaard and Gertsen, 2011; Jespersen, 2012). This leads us to formulate *Proposition-3* sating that *a collective decision-maker focuses its attention on ideas submitted by employees with moderate seniority.*

How does attention relate to value? Grounding on the theories on decision-making in crowds and in experts teams outlined in the previous sections, we submit that quality criteria to assess ideas at the fuzzy-front end of innovation are different for crowds and experts (Hienerth and Riar, 2013). We know that crowds tend to be more tied to existing technological solutions, while experts are expected to be able to understand if a proposal envisions unpredictable innovations. This may be reflected in the type of information they use for quality assessment: we suggest that crowds are more reliant on the information about the proposal provided by the inventor or generated with the commenting process; relying on this data, the crowd appreciates the value of the proposal relative to existing technological solutions. Also experts appreciate the information on ideas, but they have the opportunity to easily supplement it with additional insights about their inventors. Indeed, creative capabilities and knowledge of company's strategy greatly enhance an employee's ability to generate unconventional, path-breaking inventions – the type of inventions that experts are better suited at identifying and appreciating. It is worth noticing that information about previous innovation efforts

is readily available to the R&D management, while it is less widespread in the organization as participants may have only personal and local knowledge on the background of their colleagues. Instead, the description provided by inventors when submitting their ideas is a source of information about the idea that is easily available by all participants. Thus, formulate *Proposition-4* that *the notions of quality of crowds and experts are different, and the latter privilege indicators of quality associated to the inventor rather than to the idea.*

Research design

Empirical setting

The empirical setting of our study is the campaign "Grow Bets 2011" launched by the Danish biotech company Novozymes with the purpose of identifying inventions that had the potential of outperforming existing technologies and opening highly valuable market opportunities. Novozymes is one of the World leaders in industrial enzymes and microorganisms, selling over 700 products in 130 different countries and in 40 different industries. When the campaign was launched in October 2011, the company had 5,400 employees, of which 1,024 belonged to the centres of its R&D organisation.

Novozymes' Innovation Office – the unit of the R&D organization entrusted of developing and managing tools that facilitate idea generation and maturation – structured the campaign as an internal idea competition that was aimed at: boosting idea generation involving internal experts across R&D disciplines, departments, hierarchical levels, and sites; providing rich feedback to inventors; and assisting the R&D management in the screening and selection of promising technological opportunities.

The campaign was structured in three stages. The first one was aimed at idea generation. Preliminarily, the Innovation Office appointed senior employees of the R&D and business development organizations as members of the Screen Team. Participation was restricted to a selected group of employees with the purpose of increasing the efficiency of ideation process by involving the most knowledgeable people (Ostrover 2005); however, this choice may have reduced the variety of the knowledge base, thus constraining the potential of divergent thinking that is favourable to innovation. To prevent this potential drawback, the Screen Team choices were aimed at assuring variety of participants along the dimensions of discipline, ranking and geography.

The phase of idea generation took place on a virtual platform that was open for 12 working days.

Participants were given the option to remain anonymous when they submitted their ideas. In fact only six inventors made use of that option. Each idea represented a share in the market. They could also post comments to the ideas; inventors were allowed to reply to others' comments. The provision of a commenting platform is a distinctive feature of this idea generation campaign that is not generally found in similar projects. The commenting platform was introduced in order to provide additional feedback and information to inventors, and participants could exploit such information also for trading purposes.

Participants could use their virtual dollars endowment to trade ideas, deciding the amount of money to invest or the number of shares to divest. Transactions were not concluded by matching buy and sell orders, but with a direct interaction of participants with an automated market maker. This meant that all orders were executed instantly, and provoked a variation in the price of shares according to an algorithm developed by Hanson (2003, 2007). The value of participants' portfolios and the ranking of ideas were then updated based on the new prices. Purchase of shares in one's own ideas and short-selling were not allowed. Participants gathered information on each idea not only by looking at its price, but also from their description and comments received.

When the market closed, twenty-five ideas were evaluated by a committee composed of managers from the R&D direction in order to identify the five inventions that accessed the maturation phase. These twenty-five ideas were the ten with the highest market value and fifteen Wildcards chosen by the Screen Team among those ranked below the tenth position.

The design of this stage of the campaign provides us with the methodological opportunity to study the attributes of ideas – at a similar degree of development – that have been regarded as promising technological leads according to a collective and to an expert opinion.

Subsequently, another committee composed by members of the R&D management identified five proposals out of the 25 finalists of the idea generation phase that accessed the "maturation" stage. Maturation was aimed at further developing the inventions and to prepare a pitch to the top management. The top management decided what ideas – if any – should enter the regular process of development.

Variables and measures

We focus our attention on three outcomes of the initial stage of the campaign: the interest received by ideas from the market and the perceived quality of ideas according to the market and to the Screen Team. These outcomes are captured by the dependent variables of our study.

The variable Volume expresses the cumulated value of transactions expressed in virtual dollars received by each idea during the campaign: e.g. if share A has a cumulated value of buy orders of 1000 and a cumulated value of sell orders of 800, Volume takes the value of 1800.

The variable Value expresses the value in virtual dollars of each share when the market closed. Using the data of the previous example, the Value of share A is 200.

Wildcard is a binary variable that takes value 1 for ideas that were granted a wildcard by the Screen Team and 0 otherwise. It is important to remind that the Screen Team could grant a wildcard only to ideas ranking below the 10^{th} position, as the top-10 directly qualified to the next stage of the campaign.

We consider a set of factors that could affect the quality of ideas, and consequently are expected to be associated with the interest of traders and the value recognized by the market and by the Screen Team.

First, we try to capture the creative capability of employees by at their previous experience in patenting, scientific publications, and disclosure of innovative ideas. The binary variables "Patent", "Article" and "IdeaWeb" take value 1 if the inventor or at least one of the inventors of an idea had registered a patent, published a scientific article or posted a submission on the "IdeaWeb", an internal idea repository on which employees are encourage to post their inventions. We gathered data on previous experiences in these areas from the records provided by the Human Resource and the Library departments of Novozymes and we validated them with a search for patents in the Derwent World Patents Index database and for articles in the ISI - Web of Science database. We considered patents and articles published after 2000 in order to account for obsolescence of knowledge.

Another indicator of experience is Seniority, which measures the number of years a person has been employed by Novozymes. In the case of ideas submitted by multiple inventors we consider the Seniority of the leading inventor. In order to account for a possible curvilinear relationship of Seniority and the outcomes, we utilize in our statistical models a squared term of this variable.

The variable "Words" aims at capturing the amount of information provided by inventors. The variable counts the number of words that inventors used to describe their idea. In order to account for a possible negative effect of length on attention, we introduce a squared term of this variable that allows us at modelling a curvilinear relationship with the outcomes.

Another important source of information that is accessible to all participants is represented by the comments posted in the platform. The variable Comments counts the number comments received by each idea from participants different from the inventor. Inventors' comments are highly informative as they help clarifying the idea and add further details as requested by the market – and thus are likely to concentrate in "interesting" ideas. However, we exclude them from the analysis as inventors may have different commenting styles, some replying to each comment, and others replying to multiple comments in the same post. For this reason, the gross number of comments may be an imprecise indicator; however, the two measures are strongly correlated (…).

We use the dummy variable Team to distinguish ideas submitted by multiple inventors from those submitted by individuals. This variable allows us at capturing the role of combination of knowledge and team dynamics.

Finally, we consider two controls: the number of days an idea has been up for trading (Days traded) and the location of the inventor of the team (Location). Ideas that were submitted early in the campaign had the possibility to be traded for a longer time; this may a direct effect on Volume. Location is important to capture potential biases of the Screen Team or participants towards ideas submitted by authors belonging to specific locations. To this purpose, we distinguish three locations: Denmark, USA – that comprises three laboratories – and the Rest of the World – that comprises laboratories in Brazil, China, India and Japan.

Results

Descriptive statistics

The Screen Team invited in the campaign 145 employees, of which 109 (75%) took part in at least one of the activities: 74 submitted ideas, 82 offered comments and 101 traded in the idea market. Participants submitted 222 ideas that generated 3373 transactions and 609 comments, of which 102 were inventors' replies. Table 1 summarizes key statistics on the participants.

Table 1 Descriptive statistics on the participants in the campaign. Cases: 222

Region	**Participating**		**Seniority**	**Seniority**
Denmark	55 (50%)		0–4	32 (29%)
USA	35 (32%)		5–9	16 (15%)
Rest of the world	19 (18%)		10–14	29 (27%)
			15–24	20 (18%)
			25+	11 (10%)
			N/A	1 (1%)

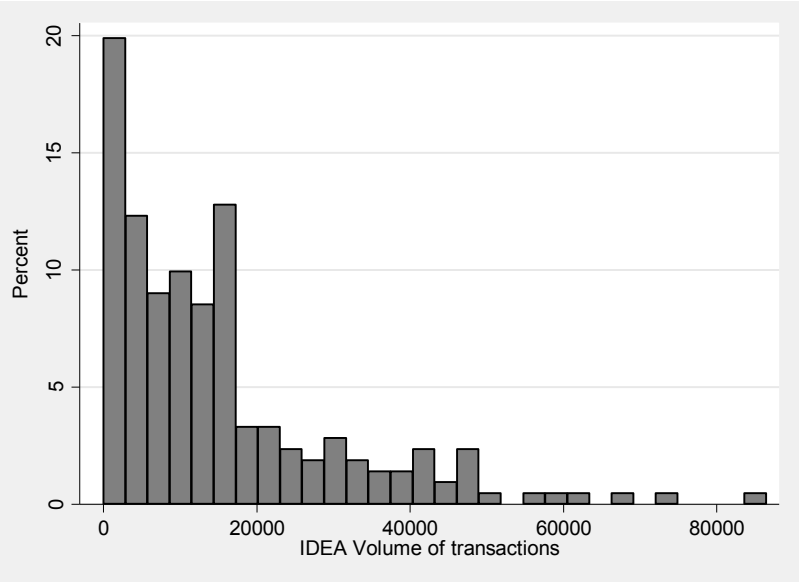
As our investigation focuses on how expert and collective intelligence differ in the use of indicators of value of ideas, we exclude from our analysis the ideas that have been submitted by anonymous inventors as well as those for which complete details on inventors are not available. We thus obtain a valid sample of 211 ideas.

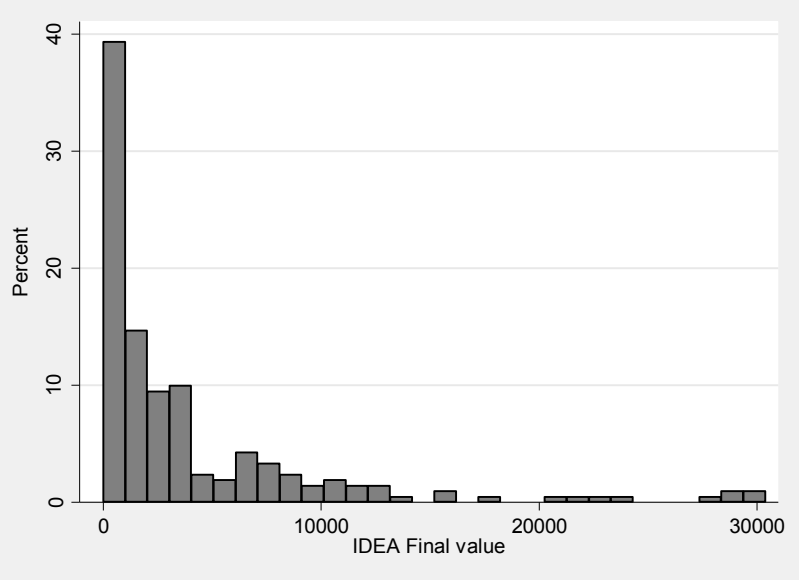
We start our analysis by examining the outcomes of the idea market. The distributions of Volume and Value are right-skewed: as Table 2 and Figure 1 show, many ideas went almost unobserved and almost 40% of them had value of zero at the closing of the market; only a small number of ideas captured the interest of traders, generating a high volume of transactions, and achieving a high evaluation: for instance, the tenth idea by value – the last one to qualify to the next step of the campaign – closed at 17560, a value that is 4.5 times the average and almost ten times the median.

Table 2 Descriptive statistics on key outcomes of the idea market. Cases: 211

	Mean (Std. Dev.)	Min; Max	Skewness	25^{th}; 50^{th}; 75^{th} centile
Volume	15162.67 (15228.76)	0; 86496	1.687	4039; 10924; 19099
Value	3922.55 (5957.24)	0; 30391	2.583	100; 1832; 4652

Figure 1 Distribution of Volume and Value [TO BE FORMATTED]





In Table 3 we begin our examination of the criteria used by the Screen Team and the market by comparing Volume and Value of the ideas that were credited as a wildcards and those that have not. As only ideas that did not qualified directly to the next step in reason of their Value were eligible to be chosen as wildcards, we narrow the analysis to ideas ranked below the 11th position. One of the 15 wildcards was awarded to an idea presented by an inventor for which we do not have full biographical record and is thus excluded from the analysis.

The Table clearly indicates that the median Value of wildcards is notably superior to that of the other ideas; the median Volume of wildcards is more than twice that of the remaining ideas. A Wilcoxon rank-sum test shows that both distributions are significantly different at 1% level in the

two groups. This pattern provides indications that the criteria of selection of the Screen Team overlap to some extent those of the market.

Table 3 Descriptive statistics on key outcomes of the idea market in the subsets defined by attribution of a wildcard. Cases: 201

	Mean (Std. Dev.) [Median] Volume	Mean (Std. Dev.) [Median] Value	Cases
Wildcard	11602.06 (21575.36) [21150]	3690.84 (8375.36) [8185]	14
Not a wildcard	12031.22 (12543.48) [9672]	3155.24 (2448.02) [1540]	187

Table 4 provides descriptive statistics on the features of inventors and of ideas and on their association with the outcomes of the idea market and with of wildcard selection process. First, we consider the signalling effect of previous experience with innovative activities. The majority of ideas has been presented by inventors who have previous experience with patenting, scientific publishing and, to a lesser extent, contribution to the IdeaWeb. This result is expected given the criteria of selection of the pool of participants. Both the market and the Screen Team tend to appreciate experience in innovation. However, ideas by those who patented and submitted ideas in the Idea Web are higher in terms of average and median Volume and Value as well as of propensity to be selected by the Screen Team; instead, experience in scientific publishing is associated with higher interest by traders, but not with higher recognition of quality neither by the market nor by the Screen Team.

The table brings to our attention that the large majority of ideas has been presented by individual inventors and those ideas tended to be more traded, better evaluated and receive more wildcards. This result is interesting, in light on the well-established notion of value of collaborative effort in the innovation process. In this case, we find an indication of the prominence of single-authored inventions. Looking at the geographical dimension, we find that the three macro-regions provided a quite similar inflow of ideas to the campaign, with a slight prevalence of Denmark. Ideas generated in Danish and American sites attracted considerably more interest and consideration than those from the Rest of the World.

Table 4 Descriptive statistics on the distribution of volume of transactions in subsets of ideas defined by categorical variables

	N. (%)	Mean (Std. Dev.) [Median] Volume of transactions	Mean (Std. Dev.) [Median] Final Value	Wildcards N. (% of not qualified)
Patent		z = -3.100***	z = -2.116**	
Yes	165 (78.2%)	16698.05 (15886.49) [12617]	4290.86 (6208.97) [2025]	12 (85.7%)
No	46 (21.8%)	9655.33 (11083.11) [6117]	2600.98 (4777.12) [1246]	2 (14.3%)
Article		z = -3.509***	z = -1.228	
Yes	148 (70.1%)	17157.11 (15419.76) [13427]	4294.95 (6351.15) [1879.5]	8 (57.1%)
No	63 (29.9%)	10477.3 (13783.1) [7425]	3047.37 (4842.29) [1597]	6 (42.8%)
IdeaWeb		z = -2.061**	z = -2.579***	
Yes	121 (57.3%)	17224.83 (16872.52) [12849]	5010.23 (6922.92) [2541]	11 (78.6%)
No	90 (42.7%)	12363.32 (12229.31) [9429]	2459.99 (3916.55) [1488]	3 (21.4%)
Team		z = 2.249**	z = 1.651*	
Yes	21 (10.0%)	10568.14 (15541.46) [4290]	3569 (7265.76) [333]	2 (14.3%)
No	190 (90.0%)	15670.48 (15149.89) [11995]	3961.52 (5816.12) [1894.5]	12 (85.7%)
Location				
Denmark	78 (33.2%)	16933.03 (13017.09) [15120]	4482.90 (5067.67) [2914.5]	7 (50.0%)
USA	61 (28.9%)	19681.28 (20216.71) [13287]	5646.20 (8517.41) [2113]	5 (35.7%)
Rest of the World	72 (34.1%)	9351.51 (10065.84) [6133]	1854.90 (2927.09) [564.5]	2 (14.3%)

Note: The statistical significance of the difference between the distributions in the subsets defined by binary variables are tested with Wilcoxon rank-sum tests; in the case of Region, a Kruskal-Wallis test is used.

Table 5 provides descriptive evidence of the relationship between outcome variables and the features of ideas that are expressed by continuous variables. Words, which can be considered as a proxy of the amount of information that an inventor discloses about an idea, and Seniority are not significantly correlated to the volume of transaction on that idea. This result could be a consequence of the expected curvilinear relationship that correlation is not able to capture.

We devote special attention to Comments, which capture additional information generated by the interaction of participants in the idea generation platform. On average, ideas received 2.03 comments; however, Table 6 indicates that the distribution of comments is skewed: only 10.4% of ideas activated a vivid debate among participants, receiving 5 comments or more; the bulk of ideas (55.5%) received from one to four comments, and more than one third no comments at all. The

Table also suggests a positive relationship between commenting activity and Volume, Value and wildcards. This effect is particularly strong for ideas that receive 5 and more comments.

For what concerns the control for the number of days an idea was up for trade, we find a weak negative correlation with Volume and Value, but not with achievement of a wildcard.

Table 5 Descriptive statistics on the relationship between continuous variables and volume of transactions

	Mean (Std. Dev.) [median]	Pairwise correlation with Volume	Pairwise correlation with Value	Widcards Mean (Std. Dev) [median] {rank sum}	Not Wildcards Mean (Std. Dev) [median]
Words	190.71 (128.66) [159]	.075	.125*	207.50 (90.56) [200.5]	189.51 (131.04) [155]
Seniority	10.23 (7.73) [10]	.101	.066	11.86 (9.51) [10]	10.12 (7.60) [10]
Comments	2.03 (2.76) [1]	.572***	.618***	4.00** (4.29) [2]	1.89 (2.58) [1]
Days traded	6.28 (5.20) [5]	-.166**	-.133*	6.79 (5.97) [6]	6.25 (5.17) [5]

Note: The statistical significance of the difference between the distributions in the subsets defined by binary variables are tested with Wilcoxon rank-sum tests.

Table 6 Distribution of comments and relationship with Volume of transactions and Wildcards

Comments	Cases N (%)	Volume Average (Median)	Value Average (Median)	Number of Wildcards (% of class excluding market)
0	72 (34.1%)	7647 (5080)	1441 (402)	2 (2.77%)
1	38 (18.0%)	10862 (11091)	2008 (986)	1 (2.63%)
2-4	79 (37.4%)	16358 (15141)	4344 (3056)	7 (9.09%)
5 or more	22 (10.4%)	41285 (42629)	13838 (10785)	4 (28.57%)

Looking at the criteria that inform the R&D management decision-making process, we find that the same factors that are associated with higher quality perceived by the market value characterize also selection of the wildcards by the Screen Team. Instead, other factors come into play in signalling the interest of the market for ideas, as reflected by Volume.

Regression analysis

In order to provide further validation of the relationship between different features of ideas and their performance in the market and in the Screen Team evaluation while controlling for possible spurious effects, we conduct a regression analysis. Model 1 takes Volume as dependent variable, while Model 2 considers Value; given the nature of the variable, we use Tobit regressions. In Models 3 and 4 we analyse attribution of wildcards; since it is a binary variable, we use a Logit regression; Model 4 differs from model 3 as it includes Value as a regressor in order to ascertain whether Screen Team's judgment is aligned with that of the market, and what other factors the Screen Team utilizes in its decisions.

Table 7 Results of regression analysis

	Model 1	Model 2	Model 3	Model 4
Dependent var.	Volume	Value	Wildcard	Wildcard
Model	Tobit	Tobit	Logit	Logit
	Coef. (Robust Std.Err)	Coef. (Robust Std.Err)	Odds Ratio (Robust Std.Err.)	Odds Ratio (Robust Std.Err.)
Value				1.364* (.139)
Comments	2.783*** (.449)	1.436*** (.180)	1.500*** (.149)	1.366*** (.196)
Patent	5.058** (2.155)	.735 (.938)	4.481 (5.271)	2.629 (3.619)
Article	1.370 (3.422)	-.421 (1.548)	.040*** (.040)	.016 (.020)
IdeaWeb	2.021 (1.801)	1.860** (.844)	3.185 (2.948)	2.362 (2.535)
Words	4.211*** (1.219)	1.728*** (.575)	1.909 (.972)	1.268 (.873)
Words Squared	-1.418 *** (.473)	-.359 (.240)	.574 (.328)	.729 (.362)
Seniority	2.945* (1.554)	.746 (.772)	2.864*** (1.295)	4.098*** (2.236)
Seniority Squared	-2.036** (.891)	-.217 (.421)	.901 (.258)	.870 (.259)
Team	-8.481** (3.597)	-.670 (1.678)	1.729 (2.635)	1.667 (2.339)
Region				
USA	5.025* (2.907)	.773 (1.200)	1.154 (1.094)	.961 (1.142)
Rest of the World	-2.332 (1.959)	-2.181** (.950)	.160 (.164)	.219* (.200)
Days traded	.329* (.176)	.248*** (.085)	1.165** (.088)	1.188* (.119)
Constant	4.460 (3.176)	-1.715 (1.693)		
/sigma	11.971 (1.014)	5.165 (.485)		
Log-pseudolikelihood	-782.69	-534.98	-35.45	-28.64
Observations	211	211	201	201

The models reveal that the only factor that plays a role for all the three outcomes of interest of traders, market value and selection by the Screen Team is the number of comments received during the game: The Comments variable is positive and significant in all the models at 1% level. The result remains robust also in Model 4 when Volume is included in the analysis. This result indicates that there is a notion of quality that is shared by both the market and the Screen Team and that is captured by the commenting activity in an idea generation platform. Furthermore, this result also suggests that participants do not only focus their attention on better quality ideas, but they also invest further cognitive resources to actively discuss them.

We do not identify other factors that are common to the three types of outcomes of the campaign – with the exception of the number of days an idea has been traded.

The length of idea description has an inverted-U shaped relationship with Volume and a positive linear relationship with Value while it does not relate to the Screen Team evaluation. This result provides an interesting insight on the decision-making process of crowds: an "optimal" level of information should be provided in order to capture the crowd's attentions, as also a collective decision maker is subject to information overflow; however, we find that the most valuable ideas are those for which more information is available. This may indicate a deficiency in information

processing: crowds may overlook valuable ideas because their inventors provide a disproportionate amount of information.

Overall, these results provide partial support to the expectations of *Proposition-1*, which expects that a collective decision maker focalizes on ideas for which a moderate amount of information is provided. We observe that the market economizes on the analysis of information provided by the inventors, but is attracted by information generated by the interaction of inventors with the crowd. This result also suggests that sources of information of inventions have different reputation and reliability for a collective decision-maker.

Turning to creative capabilities, we find that the three types of experience in innovation have different type of association with the three outcomes. Volume is positively associated with previous experience of inventors with patenting, while contributions to the IdeaWeb tend to be recognized as of higher quality. One may speculate that the two types of experience have a different visibility: the former type of information is probably more visible than the latter, and thus traders may trust more inventors with a patent; the latter is probably less effective in terms of signalling, even though inventors may be as creative and efficient than the others. Scientific experience has plays no role in the idea market, while it has a negative effect in the process of attribution of wildcards. Apparently, the Screen Team penalize inventors who have more speculative experience; however, this effect disappears when the market value of the idea is introduced in Model 4. Proposition-2, stating that ideas submitted by inventors with previous inventing experience receive more attention by a collective decision-maker, finds only partial support: only experience with patenting attracts the markets' attention, and this type of experience is not associated with a higher evaluation of the quality of the idea; on the contrary, submissions to the IdeaWeb that are associated with higher quality do not seem to attract the crowd's interest. Again, we find a possible misalignment between the attributes that attract the crowd's interest and those associated with superior quality.

We observe that ideas submitted by inventors with an average seniority attract the crowd's interest; however, this attribute of inventors is unrelated to market value. This result is fully consistent with the expectations of *Proposition-3*. Instead, the Screen Team tends to give greater consideration to seniority – that is significant in its linear but not quadratic term, i.e. there is no declining effect of seniority after a certain age. This result may hint that well-known employees who have done big part of their career in the organization are more visible to the panel of expert and thus tend to be preferred to younger colleagues.

This analysis permits to draw some conclusions also regarding *Proposition-4* about the divergence of the criteria of quality of experts and crowds, and the preference of the former for indicators relative to the inventor rather than the idea. We find that only Comments are associated with quality in both the Screen Team and the markets' evaluation. The market appreciates both attributes of ideas (Words) and of inventors (IdeaWeb), while experts' decision is strongly influenced by inventors' seniority. We can conclude that the attributes that are considered by traders and experts are indeed different; however, although using different criteria, markets and experts come to

evaluations that are to some extent coincident: in fact, we find that Value is positively and significantly associated with the selection of an idea as a wildcard.

For what concerns the controls, we find that ideas generated by employees located in the American centres tend to receive more interest than those generated in other locations, while both the market and the Screen Team tend to penalize contributions from the Rest of the World. The negative performance of ideas proposed by teams is found only with regard to Volume, but not with the other outcomes. The positive sign of Volume is an indicator of alignment in terms of definition of quality between the market and the Screen Team.

Conclusion

This paper has identified the attributes of new product ideas that attract the attention of a collective decision maker, and compared the criteria of quality adopted by the traders in an idea market to those of a pool of experts. We found that the features of an idea that attract the interest in a preference market are different from those that signal the value of the idea in the same market. The features associated with markets' interest entail both the information available on the idea and the inventors, while value is associated with only a subset of them. Specifically, we find that the former is associated with attributes of ideas such as the amount of information provided by inventors and generated by participants in the campaign through comments, and with attributes of inventors such as experience with patenting and seniority. Of these factors, only those relative to the idea are associated also with its value; furthermore, value is associated with previous experience with idea generation, but not with patenting. Experts' criteria of quality only partially overlap those of the market, as they positively reward comments and tend be aligned with the overall evaluation of the market; instead, they appreciate factors like seniority that do not emerge as criteria of assessment in the market.

However, this study is not free from limitations. One concerns the fact that the idea competition was designed in a way that the Screen Team did not evaluate the ideas ranking in the first 10 positions in the market as it did to identify the wildcards. An evaluation was performed at a later stage, when 25 ideas (the top 10 and the wildcards) were assessed. This does not allow us at directly comparing the criteria of quality of markets and experts.

Despites of these limitations, we believe that this study contributes to the literatures on the design of innovation contests and on decision making in complex settings.

We considered a case of an innovation contest that was conceived with the aim of favouring the interaction between R&D management and employees – thanks to the frequent intervention of the former in the campaign – and of stimulating knowledge exchanges among the latter. Both features are scarcely documented in the literature on idea generation management tools.

Furthermore, the study shows that despite the method of selection of the participants in the campaign that bears the risk of mirroring the preferences of the R&D management, market and experts apply criteria of evaluation that only partially overlap. The introduction of an idea market in the innovation contest extends the set of criteria of quality against with ideas are assessed.

Discrepancies in notions of quality between experts and market is consistent with the expectations of the theories on crowdsourcing and idea markets, that indeed expect the two decision-makers to focus on different aspects when evaluating ideas at the same level of development.

On a final remark, these findings are consistent with the expectations of the Behavioural Theory of the firm and specifically with the bounded rationality concept, that suggest that decisions are taken on the grounds of information that can be conveniently accessed and interpreted by actors. In this case, comments are a rich source of information available to both experts and traders, and therefore both utilize this source as an indicator of quality. While traders can easily get access to the descriptions of ideas, their knowledge of the seniority and the career track of an inventor is arguably not widespread in the market; by contrast, senior experts are more likely to be knowledgeable of profiles of their employees. Consistently, we find that – differently from the market – experts tend to consider seniority more than idea descriptions. Interestingly, we find that both decision makers consider previous creative experience of inventors; if this is not surprising in the case of experts – who are likely to know this information – it seems more interesting in the case of traders – as, probably, this information is not widespread in the market. We conjecture that previous creative experience directly translates on the quality of the idea, thus improving (or reducing, in the case of experience in academic research) the value of the idea.

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