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Open for Ideation: Individual-level Openness and Idea Generation in R&D

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Abstract

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scientists and engineers working at a large, mature organization and drawing from theories of combinatorial search, we hypothesize ? and empirically substantiate ? that openness to external ideas is curvilinearly related to ideation, indicating that benefits of openness to external sources are positive until they reach a point where negative returns set in. Probing this relationship more deeply, we examine how individuals? R&D time horizons, size of market, and knowledge breadth moderate the costs and benefits of openness. We elaborate on the implications of these results for the strategic use of openness in the innovation process for both individuals and organizations.

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Abstract

Organizations are increasingly encouraging their scientists and engineers to work with ideas originally created outside the firm. However, it is as yet unclear whether and how this individual-level increase in external search efforts impacts individuals' ideation performance, and which factors might moderate this process in turn. Using a sample of 355 R&D scientists and engineers working at a large, mature organization and drawing from theories of combinatorial search, we hypothesize – and empirically substantiate – that openness to external ideas is curvilinearly related to ideation, indicating that benefits of openness to external sources are positive until they reach a point where negative returns set in. Probing this relationship more deeply, we examine how individuals' R&D time horizons, size of market, and knowledge breadth moderate the costs and benefits of openness. We elaborate on the implications of these results for the strategic use of openness in the innovation process for both individuals and organizations.

Open innovation offers a significant opportunity for large, mature organizations to break away from their existing ways of working, engaging in wider and richer search efforts by tapping into the vast potential of ideas and technologies that exist outside the firm (Chesbrough, 2003; Laursen & Salter, 2006). External actors, such as users and suppliers, may have critical information that allows individual R&D scientists to create new combinations of knowledge that unlock significant commercial opportunities for their organization (Dahlander & Frederiksen, 2011; Franke et al., 2006). Accordingly, individuals in R&D departments are increasingly pressured by their employers to seek knowledge from external sources to develop new, valuable innovative ideas as part of the wider organizational goal of promoting open innovation. Specifically, by searching externally, individuals gain access to new ideas and resources, which, in turn, help them to sustain and stimulate corporate programs of innovation and strategic renewal. In this context, openness to external sources by individuals can provide a critical mechanism to enable exploration in large, mature organizations (March, 1991).

To date, the literature on open innovation has largely focused on the antecedents and consequences of organizational-level openness (Dahlander & Gann, 2010; Laursen & Salter, 2006; Leiponen & Helfat, 2010; Spithoven et al., 2010), often neglecting the implications of these organizational changes on individuals (for notable exceptions, see Alexy & Henkel, 2011; Henkel, 2009). As yet, there are few studies that explore how individual-level openness may explain the individuals' ability to generate new, useful, and innovative ideas for their organization. Only recently, studies have started exploring how individuals can best balance their time between internal and external engagements to take advantage of their external search activities (Dahlander et al., 2011). Yet, our understanding of the costs and benefits of openness for individuals is limited at best. In particular, we are unable to comment under which conditions

the ‘opening up’ of individuals to external sources may boost their innovative performance. Furthermore, the question of how individual and job characteristics may alter the balance between the benefits and costs of individuals’ openness to external sources remains unanswered.

In an attempt to further our understanding of individual-level openness, this paper focuses on its impact on individuals’ ability to develop new, useful, and innovative ideas for their organization. In doing so, we seek to contribute to an ongoing debate on the sources of individual-level innovation (Amabile, 1996; Scott & Bruce, 1994). Further, analyzing the contingent effect of job characteristics and individual experience, we aim to provide new insights into the contextual mechanisms that enable individuals to successfully learn from external sources and prosper in increasingly ‘open’ environments.

We follow existing literature (e.g., Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001) in arguing that individuals, like firms, should gain from openness. However, we extend this logic by maintaining that the benefits of openness for individuals should be subject to decreasing returns. Specifically, individual-level openness enables individuals to generate more useful innovative ideas, yet as the number of knowledge sources increases beyond a certain threshold the value of openness turns negative. Drawing upon theories of combinatorial search (Hargadon & Sutton, 1997; Katila & Ahuja, 2002; Nelson & Winter, 1982; Rosenkopf & Nerkar, 2001), we contend that the benefits of openness are related to the advantages of alertness and variety, while the costs of openness arise from the challenge of coordinating diverse sets of external sources. These coordination costs comprise integration costs arising from both the cognitive challenges of integrating knowledge from diverse settings, as well as approval costs arising from the burden of obtaining internal agreement for engagement with different external partners, under the shadow of Intellectual Property (IP).

Further, we hypothesize that the curvilinear relationship between openness and ideation is significantly moderated by individual and organizational factors, which alter the threshold level of openness at which the decreasing or negative returns set in. In particular, we argue that those individuals who engage in long-term research gain more from openness to external sources than those with a more near-market development focus. A longer development horizon yields more time and resources to combine broad-ranging external inputs into useful and applicable innovative ideas, and therefore increases the level of openness at which negative returns set in. We further maintain that individuals working in small markets gain less from openness to external sources than individuals active in large markets. This is because large markets offer more stable relationships for individual R&D staff to draw upon, whereas those working in small markets have greater challenges in managing external relationships. Moreover, we suggest that individuals' knowledge breadth shapes their ability to gain from openness, as individuals with high knowledge breadth are better able to manage the cognitive challenges of bringing together diverse sets of ideas from a range of sources.

We test these relationships on a rich and powerful dataset of 355 R&D scientists and engineers working for a large, mature organization. Our analysis seeks to explain how engagement with external sources allows individuals to create new, useful innovative ideas for their organization as a function of their openness to external sources. Overall, we find support for our hypotheses.

Based on our results, we make two contributions to existing literature on the management and organization of innovative activity. First, we probe the nature of individual openness to external sources and demonstrate how such openness may enable idea generation. Second, we shed light on the contingencies that shape the value of openness for individuals, demonstrating

that the nature of R&D efforts and the diversity of knowledge held by individuals significantly alters their ability to benefit from openness. As such, our results have direct implications for the tactics that individuals can use successfully in R&D settings to generate more creative ideas for their organizations.

Theory and Hypotheses

The Role of Individual-Level Openness in Ideation

R&D professionals are rewarded for their ability to develop ideas that can lead to successful new products, processes, and services for their organization. As part of this process, it has long been known that individuals working in R&D will often need to turn to external sources of knowledge to discover new opportunities or even develop their own ideas (Allen, 1977). This need arises from the fact that – although large firms may have considerable internal knowledge – this will be dwarfed by related knowledge that exists outside the firm. Users, consultants, suppliers, universities and even competitors may all provide critical knowledge to allow an individual to develop a new idea in their organization (Dahlander & Frederiksen, 2011; Franke et al., 2006).

Accordingly, many organizations are increasingly proposing strategic initiatives to make appropriate use of these external sources of knowledge, a development that can be summarized as an increasing trend toward open models of innovation (Chesbrough, 2003; Dahlander & Gann, 2010). However, the organizational goal of such initiatives – an increase in the efficiency and effectiveness of innovative activity – is contingent upon the action of individuals inside the firm (Alexy & Henkel, 2011). It is not the organization that identifies and develops new innovative ideas with others from outside the boundaries of the firm. Rather, it will be individual

researchers inside the firm, who may (or may not) become more efficient and effective by working with external actors.

Yet, our understanding of individual-level contributions to organizational open innovation efforts is modest. Henkel (2009) shows how individuals participating in corporate open innovation efforts – in this case open source software - usually do so with the organizations' best interest in mind. Alexy and Henkel (2011) explain how variance in job roles and type of corporate open innovation engagement explains differences in individual predispositions to support organizational efforts at open innovation. Similarly, Rolandsson and colleagues (2011) uncover individual-level coping mechanisms in the transition process from closed to open innovation. Recently, Dahlander et al. (2011) explore how differences in individual-level engagement in open innovation activities are linked to variance in their contribution to the performance of organizational R&D. This study considered how individuals in dedicated boundary-spanning roles balance their time between internal and external engagement and how this may drive performance as measured by patenting outcomes. Building on this study and others, we focus on the costs and benefits that accrue to individuals active in R&D when engaging in external search at the front-end of innovation, and how these are moderated by individual and organizational factors.

Our core theoretical argument draws theories of combinatorial search (Katila & Ahuja, 2002; Nelson & Winter, 1982; Rosenkopf & Nerkar, 2001) and suggests that individuals who invest greater effort into drawing in ideas from outside the firm will be more capable of generating useful ideas for their organization than those individuals who rely more on internal search. These benefits may accrue to individuals through two main mechanisms: alertness and variety. First, since each different source provides unique and divergent sets of knowledge and

resources, individuals who use a broader range of these sources gain greater inspiration and input for the generation of novel ideas. In effect, external engagement allows individuals to be more alert to new opportunities to innovate (Kaish & Gilad, 1991; Kirzner, 1973). Like entrepreneurs, individuals working in R&D who invest time and energy in external search efforts will be more attentive to new market or technological opportunities (Howell & Sheab, 2001). They will be in a better position to see new combinations that are emerging alongside or outside the firm's current product market efforts.

Second, since external sources of knowledge also contain greater variety than internal ones, external search enlarges the search scope for individuals to see opportunities for new combinations between internal and external ideas (Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001). By themselves, internal sources may lack the potential for combinatorial novelty required to support high levels of ideation (Stuart & Podolny, 1996). Often, the cumulative and evolutionary nature of intra-firm knowledge will lead to convergence rather than variety in the knowledge available inside the firm (Nelson & Winter, 1982). Thus, individuals who rely only on internal sources – or just a few external sources – may find that they lack scope for finding combinatorial novelty to ensure the creation of valuable ideas. By using (more) external ideas, individuals are better positioned to import ideas from external actors, overcoming internal tendencies – common within many large, mature organizations – to stick to "tried and tested" approaches and solutions (Hargadon & Sutton, 1997).

The Potential for Decreasing Returns to Individual-level Openness

Although the benefits for individuals of drawing ideas from many external sources can be considerable, there may be a point at which such efforts are subject to diminishing or even negative returns. Using knowledge from different knowledge sources creates coordination

challenges for individuals. Two in particular come to the fore when individuals seek to learn from external sources in large, mature organizations: integration and approval.

First, since each different source of knowledge may itself create knowledge which is distinct to its own setting, individuals will need to make considerable efforts to find ways of successfully integrating these ideas (Dougherty, 1992). By stretching oneself across a range of sources, individuals may find that they are unable to effectively combine this knowledge, as it is too diverse and discordant with what the organization knows and can do (Laursen & Salter, 2006). Especially when individuals venture into fields in which their organization lacks routines for translating or recombining unknown external knowledge (Cohen & Levinthal, 1990), individuals often have to bear the cost of making the respective external knowledge accessible to the organization. As individuals will need to establish links between different sources of external and internal knowledge to come up with a coherent innovative effort, this cost should increase exponentially with increased openness to external sources.

A second coordination challenge for individuals arising from the reliance on external sources of knowledge is the need to obtain organizational approval to engage with different sources. Despite movements towards open innovation, large R&D organizations remain extremely focused on the creation and protection of Intellectual Property, and this focus may have a significant impact on the way they engage with external sources (Alexy et al., 2009). In this context, the use of external knowledge may be constrained by organizational fears of knowledge leakage and the desire to ensure control rights over ideas. By drawing knowledge from multiple partners, individuals may find themselves facing many internal barriers to external collaboration and, as a result, they may be unable to obtain approval to develop mutual exchanges of knowledge with external sources, such as universities, suppliers and even

competitors. Moreover, as they engage with more types of partners, they increase the likelihood of having to go through an internal approval process, as each distinct source of external knowledge may operate under different contracts and norms of exchange. For example, working with non-competing firms will rely on a different set of Intellectual Property terms and conditions of exchange than working with a university partner. The complexity of this problem also increases non-linearly with an increased number of external sources of knowledge.

Taken together, by reaching out to a broad range of external sources, individuals increase coordination costs of external openness, potentially turning the benefits of additional openness into a negative sum gain for their efforts to generate new ideas. While, initially, individual-level openness should have positive effects on individuals' ability to come up with novel and useful innovative ideas, after a certain threshold, the benefits of individual-level openness – increased alertness and variety – may be outweighed by a non-linear increase in integration and approval costs. Therefore, we propose:

> *H1: Individual-level openness is curvilinearly related (taking an inverted-U shape) to ideation.*

R&D Time Horizons and the Effect of Individual-level Openness

The benefits of openness for individuals to external sources may be shaped by the time horizon of their R&D efforts. Some R&D professionals focus on short-term, near-market innovations, whereas others try to develop ideas that will reach the market in more distant years (e.g., de Brentani & Reid, 2012). We argue that those individuals focusing on the development of innovations for the long-term have a greater chance of benefitting from openness to external sources. Simply put, the longer time horizon gives them more time and resources to identify, evaluate, and harness external sources of knowledge and coordinate the input from different complementary sources. Given the costs of engaging with a diverse array of partners is likely to

be high, the additional time and resources concomitant to longer R&D time horizons will be instrumental in enabling individuals to effectively learn from external sources and to convert this knowledge into a form that is usable by the organization. In contrast, those individuals who work on short-term R&D efforts need to 'run fast' and will have little opportunity to hone and graft external ideas to fit internal needs and resources. As a result, they will have a harder time gaining from openness. Also, they face more pressing coordination problems as they have to ensure that external ideas can be harnessed to the short needs of the firm. In effect, this leaves them disadvantaged with colleagues who have more opportunities to experiment with external ideas and sources. Thus,

> *H2: The time horizon of individuals' R&D efforts moderates the relation between openness and ideation, such that the threshold level of openness at which diminishing or negative returns set in is higher for those with a long-term focus.*

Market Size and the Effect of Individual-level Openness

R&D efforts in large, mature organizations are usually directed to meeting the needs of existing markets of their organization (Leonard-Barton, 1992). Such a focus has significant implications for individuals working in R&D departments, as they will be expected to align their R&D efforts to the needs of the divisions they are associated with. This logic applies in particular to individuals active in R&D departments that serve business units active in large, established product markets. Here, individuals usually have to focus their R&D efforts toward enhancing the value of existing assets, ensuring the organization is able to fully profit from its high fixed costs investments and current asset stock (Dougherty & Heller, 1994).

As a result, the direction of an individual's R&D efforts toward particular markets may have significant implications for their ability to gain from openness to external sources. Individuals attempting to develop innovations for a large, established market of their

organization will be able to draw upon the organization's rich stock of existing relationships with external parties. Large, established product market units rely on a strong and stable set of reliable and vetted external partners. In fact, many of these external partners may be focused on meeting the firm's specific needs, such as external consultants or suppliers. Often, relationships with these external parties are covered by formal collaboration and alliance agreements, allowing individuals within the firm to quickly and effectively work with these external partners. They may further be sustained by repeated collaboration, leading to trust between the focal firm and its external partners (Gulati, 1995). As a result, individuals working in these departments will be able to effectively reach out to external sources without incurring the organizational costs of gaining approval or justification for external engagement.

Moreover, these external partners will develop knowledge that will be well aligned to the organization's own capabilities and know-how (Lane & Lubatkin, 1998), suggesting that organizational routines to transfer and adopt external knowledge readily exist. In addition, participation in external communities of practice and monitoring of competitors are means – widely available in these more mature markets – through which individual workers can draw support to develop new ideas, further reducing the individual-level integration cost (Laursen & Salter, 2006). In sum, working for large markets will make it easier for individuals to benefit from the use of external sources to generate new ideas, as the costs of coordinating knowledge from these externals will be relatively modest.

In contrast, for individuals working for small markets, drawing knowledge and expertise from external actors is likely to be much more difficult. First, they are likely to have to rely on less developed links to external suppliers of knowledge and ideas, leading to a corresponding lower level of aligned and focused internal and external support. Second, creating additional

links will be relatively more costly for individuals working in small markets than for individuals working in large markets. This is because small market departments may be weak within the intra-organization network relative to colleagues in large markets units (Tsai, 2001). Since large-market units account for the leading part of the organization's overall revenue, they can command greater organizational attention and support for their efforts. In contrast, individuals working for small-market units operate on the margins of the organization and therefore may struggle to win management support and approval for their initiatives to engage with external sources. This will make it harder for them to learn effectively from external sources as such learning opportunities may be proscribed by senior management, who are unwilling to meet the organizational costs of building a relationship with a new external source, such as negotiating a formal IP agreement. Taken together,

> *H3: The size of the market at which individuals' R&D efforts are directed moderates the relation between openness and ideation, such that the threshold level of openness at which diminishing or negative returns set in is higher for those working for large markets.*

Individual Knowledge Breadth and the Effect of Individual-level Openness

The ability of an individual to benefit from openness to external sources is not purely determined by the direction of their R&D efforts or their organizational setting; it is also a function of their personal ability to bring together and connect different sources of knowledge (Kolb, 1984). Fundamentally, individuals who have a broader knowledge base to begin with, should be more effective at learning from external sources, allowing them to decrease the amount of time and resources they spend on accessing outside knowledge. Put differently, we would expect these individuals to generally bear lower integration costs than their peers.

For example, the literature on absorptive capacity is clear that individuals and organizations that have a wider breadth of knowledge may be better positioned to learn from

external sources (Cohen & Levinthal, 1990). Possessing knowledge of different domains should give individuals a combinatorial advantage over their more narrowly focused colleagues (Hargadon & Sutton, 1997). By engaging in different knowledge domains, individuals will be better able to see opportunities to learn from different areas, and find useful and new combinations from disparate sources. This breadth will not only support their ability to generate ideas; it will also enable individuals to more successfully harness external sources for ideation. By maintaining an interest in different domains of knowledge, individuals will have a greater cognitive capacity to integrate diverse and even potentially conflicting sets of information. They may also exhibit more patience when seeking to find ways of integrating initially incompatible ideas. As a result, their knowledge breadth will allow them to more successfully utilize a broad range of external sources and profit from openness, providing them with the cognitive ability to overcome some of the coordination costs associated with the use of a wide range of external sources. Thus,

> *H4: Individuals' knowledge breadth moderates the relation between openness and ideation, such that the threshold level of openness at which diminishing or negative returns set in is higher for those with a broad range of expertise.*

Data and Methods

Sample and Data Collection

This study is based on a sample of senior scientists and engineers working for a large technology-intensive multinational corporation which, for reasons of confidentiality, we will refer to as Neptune. This company has a dual-career structure in place that allows a separate career progression path for technical professionals and for managers in the R&D department. In Neptune, all R&D projects must go through a 'stage-gate' system which operates both at the idea generation phase as well as at the idea implementation phase of a project (Cooper, 1985, 2008;

for a more recent overview, see Martinsuo & Poskela, 2011). This organization strongly encourages its R&D staff to be open to external sources of knowledge and to engage with external parties, whether academics, suppliers or start-up companies. It is also highly focused on the capture of IP and organizes its external engagement carefully to ensure it is able to secure downstream IP rights from its external collaborations.

To better understand the innovation process in this organization and the role that openness has in the innovation activities of these individuals, we carried out interviews with 25 senior scientists and engineers and 10 interviews with senior R&D managers. In these exploratory interviews we realized that, although all R&D staff are expected to have a strong external orientation, there were some important contingency factors explaining why certain individuals were more successful than others in leveraging their external engagement in their innovative activities.

The interviews were instrumental in helping us design an anonymous survey, which targeted all 600 senior scientists and engineers. The survey was administrated in an electronic format in June 2010 after a pilot with a group of 10 individuals, during which we ensured that questions were unambiguous and unlikely to solicit socially desirable responses (Podsakoff et al., 2003 see more on common-method bias in a separate section below). In total, we received 408 responses, which correspond with a response rate of 67%. However, because of non-complete responses, our final sample contains 355 individuals. Analysis of non-response bias, comparing demographics of respondents and non-respondents, as well as comparing the answers of earlier and late respondents showed now significant differences (Armstrong & Overton, 1977).

Dependent Variable

Ideation. Our measure of the ability of individuals to generate new ideas is based on the

number of projects that have entered a crucial gate in Neptune's stage-gate system (Cooper, 1985, 2008), thereby also addressing a call for more research into later stages of the front-end of innovation (Kijkuit & van den Ende, 2010). More precisely, we asked respondents to indicate how many times over the past three years their engagement in R&D had resulted in projects being presented at the stage-gate that marks the transition between idea generation and idea implementation. At this stage-gate (gate 3 in Cooper's original model), it is decided whether further major investments required for the downstream development and implementation of specific, well-developed ideas can be justified.

The number of projects entering this 'implementation gate' is a relevant success criterion in terms of ideation for all R&D scientists in our sample for several reasons. First, all ideas developed by members of Neptune must travel through the stage-gate process. Second, our sample of R&D scientists and engineers are primarily focused on the front-end of the innovation process, and do not have significant creative input and further involvement in downstream decision-making after the implementation gate. Moreover, since Neptune has considerable options and heavy downstream investment costs, it has to severely restrict the number of ideas entering later phases of the stage-gate process. As a result, individuals that succeed in bringing their ideas to this gate have achieved a significant milestone. Finally, when being assessed at the implementation gate, ideas have already passed several prior selection gates, thus they have at least some merit as assessed by the wider organization. Accordingly, our measure represents the outcome of an objective evaluation process conducted by several members of the organization, and should in turn be unaffected by individual evaluation biases commonly found in studies looking at the value of innovation projects (Blindenbach-Driessen et al., 2010).

The variable is a single-item measure, which may be subject to some concern. However,

as suggested by Rossiter (2002) and demonstrated by Bergkvist and Rossiter (2007), a single-item scale is recommended when capturing a concrete and singular object or phenomenon. The number of projects entering the stage-gate system fulfill these two criteria.

Independent Variables

Openness. The degree of openness of individuals' search efforts was measured by a survey question which asked respondents to indicate how often they interacted with a range of different external parties to gain ideas, technical solutions or expertise during the last year (see Dahlander et al., 2011 for a similar measure). The list, developed on the basis of existing research (e.g., Laursen & Salter, 2006) and refined through interviews and the survey pilot, seeks to be comprehensive and mutually exclusive and covers the most critical sources of external knowledge individuals rely upon in their R&D efforts. Table 1 reports descriptive statistics of the external sources listed. In general, it appears that the use of external sources is common among our population of respondents.

Our measure of openness is akin to Allen's (1977) measure of the information sources of scientists and engineers, as well as Hambrick's (1982) measure of 'environmental scanning' used in team and manager studies (see also Howell & Sheab, 2001). This approach of listing sources to measure search has also been used in studies of entrepreneurship (Kaish & Gilad, 1991) or as a measure of organizational-level openness (Laursen & Salter, 2006; Leiponen & Helfat, 2010; Spithoven et al., 2010). The internal reliability of our individual-level variable is high (Cronbach's alpha = .71).

INSERT TABLE 1 HERE

Time horizon of R&D efforts. To measure this variable we asked respondents in our survey to indicate when their R&D work is expected to reach or have an impact on the market:

within two years from now or more than two years in the future. We based our time horizon of two years on our interviews and organizational setting, where this period was considered a long-term R&D investment. We then constructed a dummy variable, equal to one if the results of the R&D efforts of an individual will reach the market in more than two years.

Market size. This variable is a dummy variable, which is equal to one if the market targeted by the innovative efforts of an individual is among Neptune's largest product markets. Specifically, we ask whether individuals' R&D efforts are targeted at markets in which Neptune is currently achieving revenues above a certain threshold.[1]

Knowledge breadth. We measure the breadth of the individuals' expertise by asking respondents to indicate how many communities of practices within Neptune they are member of. Neptune has an effective knowledge management system, which includes best practice repositories, expert yellow pages, and communities of practices. Members of communities of practices provide advice and support to colleagues working on similar topics. By engaging in different communities, individuals signal their expertise and engagement in different areas of knowledge development inside the firm, keeping them abreast of a range of technical problems as they emerge in different areas of the firm's practices (Wenger et al., 2001).

Control Variables

We include a number of other variables which have been shown to influence ideation and individual-level innovation to ensure non-spuriousness of our measured effects. Both *intrinsic* and *extrinsic motivation* can play a role in determining creativity (Amabile, 1996; Ryan & Deci, 2000). We derived measures of intrinsic (Cronbach's alpha = .69) and extrinsic motivation (Cronbach's alpha = .69) from an 8-item scale adapted from Rynes, Gerhart and Minette (2004).

[1] Not disclosed for reasons of confidentiality.

Another important variable in driving the generation of new ideas is the extent to which the individual perceives the work-environment as being supportive of creative efforts (Scott & Bruce, 1994). The scale used derives a measure of *climate for innovation* (Cronbach's alpha = .86) consisting of eight items taken from the original 22-items scale developed by Scott and Bruce (1994). We also take account of a number of individual-level characteristics including *gender*, *organizational tenure* (number of years spent working for Neptune), and *seniority* (three-point scale capturing the official levels of seniority used by the company). Furthermore we control for the location of an individual by including a dummy variable equal to one if a researcher works at the company's *headquarters*. Finally, we included dummy variables to control for differences in ideation among Neptune's different *business units* and varying *job functions.*

Common-method Bias and Validity of Measures

Because both our dependent and independent variables are derived using the answers to the same survey instrument, our results might be affected by common method bias (Podsakoff et al., 2003). We adopted a number of measures in the design of our surveys to avoid this problem. First, we strictly ensured psychological separation of our constructs. Second, we repeatedly pointed out that responses would be treated confidentially and remain anonymous to minimize issues of evaluation apprehension. Third, we used different response formats, asked more sensitive questions at the end of the questionnaire and more 'neutral' questions at the beginning, and used an inductive approach based on our interviews to develop our scale items. Fourth, we sought to measure our dependent and independent variables on the basis of individuals' behavior rather than their attitudes, capturing information on concrete and context-specific outcome variables. Fifth, we formally tested for the presence of common method bias in our data by

carrying out the Harman's single factor test including all 55 items included in our survey. We found 11 factors, of which the first accounted for 18% percent of the variance, which suggests that common method bias should not be of major concern. Nonetheless, we applied the marker variable technique proposed by Lindell and Whitney (2001). When controlling for 'environmental concern at work', the partial correlations between all our variables of interest remained unchanged, further supporting our notion that common method bias should not be a concern.

Analytical Procedure

We tested our hypotheses using negative binomial models due to the presence of over-dispersion in the data. However, the non-linearity of the negative binomial model introduces some challenges in the interpretation of the interaction terms, especially when, as in our case, one wants to assess the effect of a moderating variable on a curvilinear relationship between an independent variable (*openness*) and the dependent variable (*ideation*). To address this issue, we follow Zelner (2009) in deriving via simulation the predicted number of new ideas for different values of each moderator variables whilst keeping all the other variables at their means. We then graph the predicted count against the entire range of the openness variable to assess whether the effect of the moderator variable significantly shifts the threshold level in the number of external sources into the hypothesized direction.

Finally, we take several precautions to address potential multicollinearity issues. Importantly, high correlations between main effects and interaction terms are to be expected and different from problems of multicollinearity (Echambadi et al., 2006). Still, to ease interpretability of our findings, we standardized all variables prior to computing interactions. In addition, while not proof of the absence of multicollinearity, variance inflation factors for all our

models exhibit a maximum value of 5.8, which is below the common threshold value of 10. In addition, we see no significant unexpected shifts in t-statistics caused by backward or forward inclusion of variables (see Maddala & Lahiri, 2009, in particular Chapter 7).

Results

The summary statistics and bivariate correlation of all our variables are shown in Table 2. On average, an individual has been engaged with six external sources of knowledge and is a member of three communities of practice. More than half of the senior scientists and engineers in our sample target one of Neptune's largest markets and for 65% of them the outcome of their R&D efforts will reach the market in more than two years.

INSERT TABLES 2 AND 3 HERE

In Table 3, we report the results of the negative binomial regression analysis. To be conservative in drawing conclusions from our models, we will test improvements in model fit using likelihood ratio tests when adding the interaction effects (with the linear and quadratic terms) to our model. Model 1 is our baseline model and only includes the control variables. Model 2 introduces the number of external sources as linear and quadratic terms. In Models 3 to 5, we include separately each of the hypothesized moderators to identify their respective contributions to improving model fit. Finally, Model 6 represents the full model.

Hypothesis 1 posits an inverted curvilinear relationship between openness and the number of ideas generated by an individual. This is supported by our results; for ease of interpretability, by looking at Model 2 we clearly see that the linear term is positive and significant ($p<0.01$) while the squared term is negative and significant ($p<0.01$). Relative to Model 1 we observe an increase in the goodness of fit of the model as suggested by the log-

likelihood ratio test.

For the same reason of mathematical simplification, we also employ Model 2 to estimate the maximum of the inverted U-curve. As shown in Figure 1, we find that the negative returns to openness set in if an individual uses more than six sources. As nearly half of the observations in our sample have values of openness greater than the flexing point at six sources, it is reasonable to suggest that our model predicts the presence of negative and not only decreasing returns. To formally test for the presence of negative returns, we followed Laursen and Salter (2006) and estimated a model replacing *openness* with a set of dummies, which are equal to 1 for different cut-off values of the number of external sources used. More precisely, *dum0* is equal to 1 if the openness variable varies between 5 and 9 (the range around the maximum of the curve), and 0 otherwise. The other dummy variables were derived in a similar fashion for the following range of values: 0 sources (*dum1*); 1-2 sources (*dum2*); and 10-11 sources (*dum3*). We then estimated a model using all the control variables and all the dummy variables except for *dum0* (the reference category). All the dummy variables are negative and significant ($p<0.01$), which indicates that – compared to having between 5-9 external sources - there is a negative impact of having fewer than 5 or more than 9 external sources. This further supports the presence of negative returns as predicted in Hypothesis 1.

INSERT FIGURE 1 HERE

We now turn to the second hypothesis on the moderation effect of the *time horizon* of an individual's R&D efforts. Consistent with Hypothesis 2, both interaction terms with the linear term of the openness variable and with its squared term are highly significant ($p<0.01$) and the inclusion of these two variables improves the model fit significantly. To better interpret the effect of this moderating variable on the threshold level of openness at which negative returns set

in, we graph it using the procedure explained above (Zelner, 2009). Figure 2 shows that – in line with the prediction of Hypothesis 2 – the maximum of the curve describing the relations between openness on ideation shifts to the right for individuals working mostly on long-term R&D projects (compared to those with a short-term R&D focus). We also find that the positive slope of this curve is steeper, while the negative slope is flatter if individuals' R&D efforts have a long-term focus. This suggests that a longer time horizon of R&D may amplify the benefits of using a greater number of external sources for ideation, while it dampens the costs of coordinating a large number of different external sources.

INSERT FIGURE 2 HERE

Regarding the potential moderation effect of the *market size* variable, we find that the two interaction terms introduced in Model 4 are both significant, but the log-likelihood test indicates there is no improvement in model fit relative to Model 2. Also, in the full model, only the squared term remains significant, suggesting that we find only weak support for Hypothesis 3. Nonetheless, the graphical representation of the effect does lend some additional support to the original hypothesis. As Figure 3 clearly shows the size of the market targeted by the individuals' R&D efforts increases the level at which the marginal impact of openness on ideation becomes negative. This suggests that individuals targeting large markets with their R&D efforts might indeed be able to manage a larger number of external sources for the benefit of idea generation.

INSERT FIGURES 3 AND 4 HERE

Our final hypothesis concerned the interaction between openness and *knowledge breadth*. Consistent with Hypothesis 4 we find that knowledge breadth significantly moderates the relation between openness and ideation; both interaction terms are strongly significant ($p<0.01$)

in the full model. Furthermore, the goodness of fit of Model 4 improves relative to Model 2, highlighting that these variables contribute to the explanatory power of our model. Figure 4, however, indicates that – contrary to our predictions – the moderation effect of knowledge breadth does not shift the threshold level of the openness where negative returns set in, but rather it affects its slope. For both the upward and downward part of the inverted U-shaped curve, increased levels of individuals' knowledge breadth flatten the curve describing the relation between individual-level openness and ideation. This suggests that – relative to individuals specialized in a limited number of knowledge fields – individuals with a broad range of expertise more easily benefit from a low number of external sources, whilst at the same time experiencing a dampened impact of having a large number of different external sources.

Implications and Conclusion

Discussion of Results

The shift towards open innovation in many large, mature organizations creates both opportunities and challenges for professionals working in R&D. This paper seeks to contribute to our understanding of the cost and benefits of openness, helping to reveal its implications for innovations on ideation. As Allen (1977) suggested, individuals working in R&D operate in an 'open system', drawing ideas from a range of external sources. Accessing external knowledge from multiple types of sources may help individuals gain access to a richer and more diverse pool of knowledge, as well bring them in the position to finding new combinations of internal and external ideas. At the same time, external search is not without cost. It requires effort and time to effectively engage with external ideas and turn the latent potential of these ideas into something that is valuable and useful for the organization (Cohen & Levinthal, 1990). Although it has long been recognized that external search may be useful for individuals as well as

organizations, there have been relatively few attempts to explore the costs and benefits of openness for individuals and to examine the critical factors that moderate this relationship.

Using an analysis of 355 R&D scientists and engineers working for a major international organization, we found strong evidence that openness to external sources can have significant benefits for individuals' ability to generate new and valuable ideas for their organization. By being open, individuals can gain the advantages of variety and alertness, making them better prepared to develop new, valuable ideas for their organization. However, we also found significant decreasing and even negative returns to openness. Finally, we uncovered organizational- and individual-level moderators of the effect of individual-level openness on ideation.

Contributions to Theory

With this study, we make two contributions to the literature on the management and organization of innovative efforts. First, we establish a link between individual-level openness and idea generation. Importantly, the relationship that we document is of curvilinear nature. That is, as openness to external sources may stimulate individuals' alertness to market or technological opportunities and grants them access to a larger variety of knowledge from which to draw and build new ideas, higher levels of openness boost their performance to develop innovative ideas for their organization. Yet, we also suggest that after a threshold value of individual-level returns to openness turn negative due to (non-linearly) increasing coordination costs associated with the use of diverse sets of external knowledge. More precisely, individuals who have a very large number of different types of external sources of knowledge experience disproportionate integration costs arising from the cognitive effort associated with coordinating knowledge from disparate sources as well as approval costs arising from the challenge of

obtaining administrative approval for broad external engagement.

By explicating these mechanisms, we have attempted to enrich our understanding of the costs and benefits of openness for individuals and their organizations, showing how open innovative efforts affect R&D outcomes of high relevance to the organization. Our approach helps to reveal some of the cognitive challenges that high levels of openness may elicit, as stressed by Koput (1997) and later by Laursen and Salter (2006). It also helps to further uncover how internal challenges of coordinating external engagements under the shadow of IP may also shape the nature of individual's and organizational search efforts. It suggests that beside the challenge of balancing their time across internal and external engagements (Dahlander et al., 2011), individuals 'open for ideation' face the challenge of coordinating the fruitful use of disparate knowledge inputs and the management of various types of partnerships. Taken together, this insight allows us to extend current literature on open innovation by explicating the effects of individual-level coordination costs of openness and how these relate to performance outcomes. Notably, these results are consistent with firm-level studies of the decreasing returns to openness (Laursen & Salter, 2006; Leiponen & Helfat, 2010). In our sample, a significant share of individuals would appear to be too open and, as a result, they were unable to generate as many useful or valuable ideas as their colleagues with a more balanced approach to openness. This suggests that organizational attempts to encourage, support, and train their R&D staff to engage in greater openness needs careful management. The use of a broad range of external sources of knowledge may actually lower the potential for ideation. Therefore, openness is a useful but limited tool that needs to be handled with considerable managerial care and attention.

As our second contribution, we show that the value of openness for individuals is shaped by their organizational context and individual-level characteristics. Individuals who work on

short-term, near-market products, processes, and technologies gain less from openness than those individuals that focus on long-term efforts, and negative effects for these individuals also set in faster. In turn, this suggests that openness to a broad range of external sources in fast-paced or high-velocity environments may be more costly for individuals than narrow, more directed external search. This result is consistent with Laursen and Salter's (2006) suggestion that organizational benefits of narrow or directed use of external sources are greater for more radical innovations, which are often longer-term in nature, than more incremental near-market innovative efforts. Relatedly, we found weak support for our assertion that individuals targeting large markets stand to gain more from openness and suffer less from coordination costs. Somewhat contrary to our initial expectations, we found that individuals working in small markets attain higher benefits from low levels of openness to external sources relative to those targeting larger markets. Yet, consistent with our original expectation, the costs of openness to many external sources do set in earlier, as a consequence of which the openness curve becomes more steeply negative for these individuals working for small markets. This, too, would suggest that narrow, targeted open innovation efforts are more appropriate (in the sense that they increase innovation performance) when organizational contingencies exacerbate the coordination costs associated with individual-level openness, a finding that is also of direct relevance to practicing managers.

Regarding individual-level contingencies, we found that knowledge breadth is associated with obtaining more benefits and fewer costs from openness. Knowledge breadth appears to allow individuals with greater cognitive capacity to take advantage of openness, and therefore it suggests that being active in different areas of technology or knowledge may help them to gain from engagement with external sources. This suggests that a broader knowledge base allows an

individual to better cope with the challenges posed by dealing with a high number of sources, in particular decreasing coordination costs associated with integration. As such, knowledge breadth should be an essential component of forming the individual-level absorptive capacity (Lewin et al., 2011; Volberda et al., 2010) necessary to benefit from open innovation activities. However, high breadth does not appear to alter the threshold level at which openness becomes negative, suggesting that the integration capability originating from knowledge breadth is conceptually distinct from other dimensions of the coordination costs related to the allocation of attention.

Limitations, Suggestions for Future Research, and Conclusions

This research is subject to several important limitations. First, we draw on a single organization, which limits our ability to generalize about other settings. Although this company is diverse and contains many fairly autonomous units, these still exhibit consistent HR practices and IP policies. Looking across a range of organizations would help us to understand whether the costs and benefits to openness we document are also present elsewhere, as suggested by the fact that – in a different research setup – Dahlander et al. (2011) also find positive returns to individual-level openness. Nevertheless, future empirical research, in varying industrial contexts and with organizations of different sizes, is needed to further corroborate our findings.

Second, although our list of external sources is fairly comprehensive, we only capture information on the frequency of an individual's engagement with a broad range of different types of knowledge source rather than their use of multiple actors from each type. For example, we can only say if an individual works with universities frequently, not the number of university partners they engage with. It may be that the breadth of individuals' search efforts within each knowledge source significantly shapes costs and benefits of openness. Future empirical work that builds on a modified list of questions might address this shortcoming.

Third, since we sought to capture ideas that were new and valuable, our measure of ideation is based on ideas that have successfully moved to an advanced stage in the organization's stage-gate process. It may be that ideas that individuals garnered from external sources are stopped before this stage and we are not able to observe the full range of ideation created by an individual's search efforts. A study that focused on ideas at different stages of the innovation process would help enrich our understanding of the impact of openness across the innovation journey (see Love et al., 2011 for a study of this type for organizations).

Finally, in a cross-sectional study, it is difficult to establish the definite and directional causal structure between dependent and independent variables. Research based on panel data, repeatedly measuring openness and ideation and using a model with lagged variables, could help to ultimately confirm the underlying causal structure of this relationship.

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Table 1. The use of external source of knowledge

Variable	No. Individuals	Percentage
Suppliers	309	0.87
Universities	247	0.70
Customers and end users	242	0.68
Consultancy firms	222	0.63
Non-competing firms	210	0.59
Professional and trade institutions	198	0.56
Individual external inventors	167	0.47
Private research institutes	161	0.45
Innovation brokers	117	0.33
Standard setting organizations	86	0.24
Competitors	83	0.23

Table 2 Descriptive statistics and bivariate correlations (n=355)

		Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11
1	Ideation	2.01	2.33	0	12											
2	Openness	6.22	2.72	0	11	0.06										
3	Time Horizon	0.65		0	1	0.02	-0.01									
4	Market Size	0.56		0	1	-0.01	-0.12	0.00								
5	Knowledge Breadth	2.56	1.49	0	17	0.12	0.17	0.04	-0.10							
6	Extrinsic Motivation	0	1	-3.30	1.72	0.02	0.00	0.02	-0.05	-0.07						
7	Intrinsic Motivation	0	1	-4.42	1.64	-0.04	0.12	0.01	-0.01	0.05	0.02					
8	Innovation Climate	0	1	-2.78	1.92	0.04	-0.09	0.08	0.07	0.01	0.04	-0.02				
9	Gender	0.22		0	1	0.05	-0.09	0.06	-0.12	-0.05	0.09	0.10	-0.06			
10	Seniority	1.26	0.49	1	3	0.00	0.09	0.14	-0.01	0.05	-0.09	0.16	0.06	-0.03		
11	Tenure	19.96	7.54	0	44	-0.06	-0.09	0.01	-0.10	0.01	-0.03	-0.02	-0.03	0.06	0.33	
12	Headquarters	0.63		0	1	-0.10	-0.05	-0.02	-0.04	0.04	0.11	0.07	-0.12	0.00	0.20	0.31

Correlations greater than |0.10| are significant at 5%.

Table 3 Negative Binomial Models for Idea Generation Rate (n=355)

	1	2	3	4	5	6
Extrinsic Motivation	0.065	0.079	0.079	0.087	0.077	0.088
	(0.020)***	(0.017)***	(0.019)***	(0.015)***	(0.021)***	(0.019)***
Intrinsic Motivation	-0.066	-0.063	-0.06	-0.064	-0.064	-0.064
	(0.030)**	(0.027)**	(0.026)**	(0.030)**	(0.027)**	(0.030)**
Innovation Climate	0.061	0.098	0.098	0.101	0.094	0.098
	(0.021)***	(0.005)***	(0.005)***	(0.009)***	(0.003)***	(0.003)***
Gender	0.12	0.155	0.174	0.152	0.145	0.159
	(0.022)***	(0.024)***	(0.019)***	(0.033)***	(0.027)***	(0.021)***
Seniority	0.053	0.003	0.017	0	0.037	0.041
	(0.093)	(0.095)	(0.094)	(0.090)	(0.075)	(0.074)
Tenure	-0.006	-0.006	-0.006	-0.006	-0.008	-0.008
	(0.003)**	(0.003)	(0.003)**	(0.004)*	(0.003)***	(0.003)***
Headquarters	-0.165	-0.133	-0.149	-0.124	-0.169	-0.169
	(0.116)	(0.138)	(0.135)	(0.121)	(0.133)	(0.114)
Time Horizon	-0.073	-0.051	-0.186	-0.06	-0.077	-0.185
	(0.094)	(0.105)	(0.102)*	(0.116)	(0.081)	(0.107)*
Market size	0.006	0.027	0.038	-0.013	-0.006	-0.032
	(0.075)	(0.052)	(0.059)	(0.074)	(0.053)	(0.079)
Knowledge Breadth [a]	0.114	0.105	0.086	0.104	0.016	0.01
	(0.033)***	(0.030)***	(0.028)***	(0.022)***	(0.029)	(0.025)
Openness [a]		0.073	0.271	-0.04	0.04	0.083
		(0.006)***	(0.023)***	(0.075)	(0.018)**	(0.068)
Openness squared		-0.16	-0.284	-0.165	-0.152	-0.257
		(0.016)***	(0.015)***	(0.020)***	(0.012)***	(0.011)***
Openness x Time Horizon			-0.269			-0.224
			(0.032)***			(0.039)***
Openness squared x Time Horizon			0.164			0.129
			(0.025)***			(0.036)***
Openness x Market Size				0.202		0.222
				(0.113)*		(0.136)
Openness squared x Market Size				0.029		0.024
				(0.010)***		(0.007)***
Openness x Knowledge Breadth					-0.073	-0.05
					(0.025)***	(0.025)**
Openness squared x Knowledge Breadth					0.124	0.115
					(0.026)***	(0.019)***
Constant	1.015	1.145	1.224	1.164	1.193	1.269
	(0.126)***	(0.110)***	(0.124)***	(0.104)***	(0.086)***	(0.109)***
Log-likelihood	-664.36	-660.73	-658.47	-659.43	-658.46	-655.5
Log-likelihood ratio test (df) [b] - χ^2		7.26(2)**	4.52(2)*	2.59(2)	4.53(2)*	10.45(6)*

Robust standard errors for two-tailed tests clustered by seniority. Divisions and job function dummies included.

[a] Variable is standardized by subtracting the mean from the value and dividing by the standard deviation.

[b] Compares Model 2 to Model 1; Models 3, 4 , and 5 to Model 2; Model 6 to Model 2.

* significant at 10%; ** significant at 5%; *** significant at 1%

Figure 1 Predicted effect of openness on the number of ideas generated

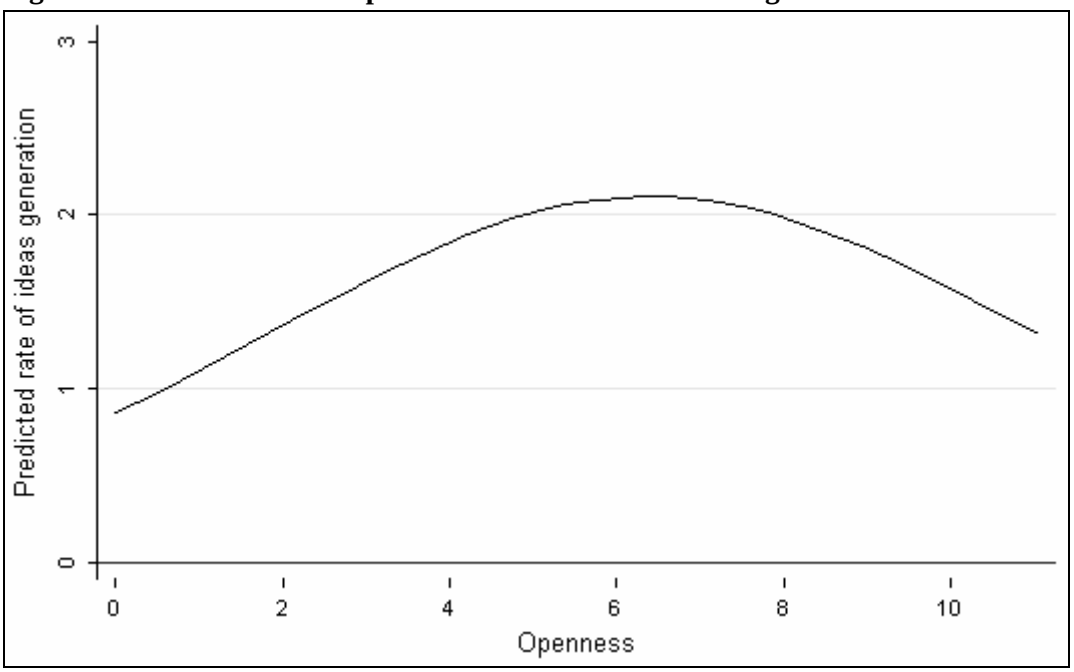


Figure 2 Moderation effect of time of horizon of R&D

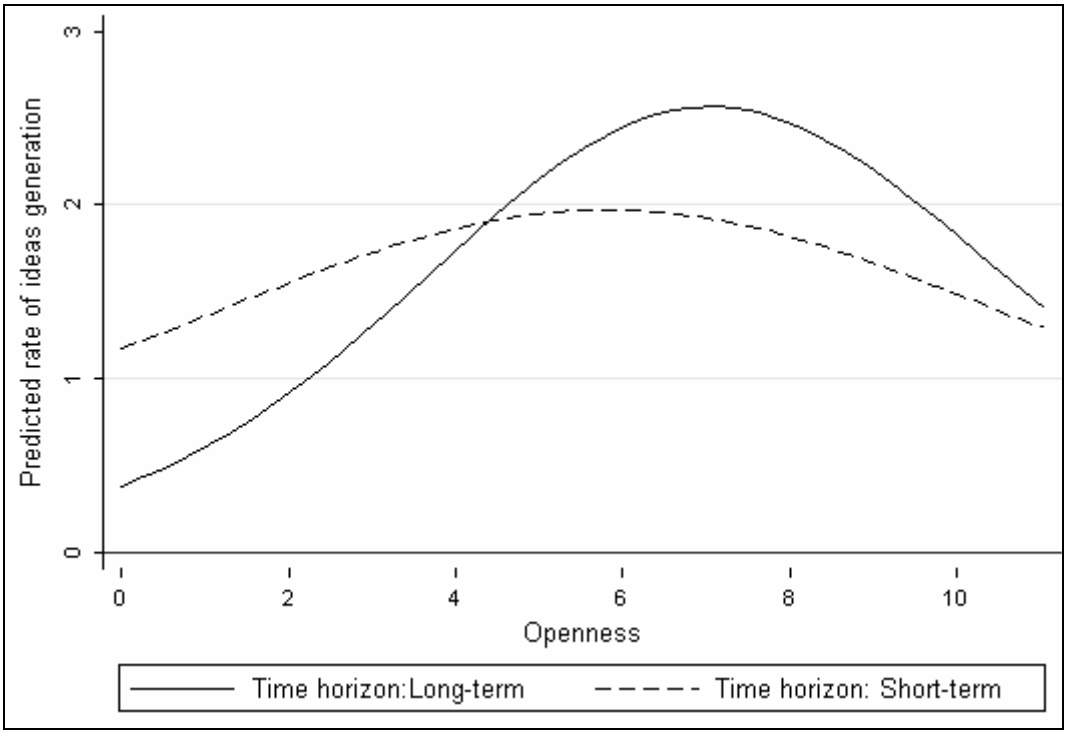


Figure 3 Moderation effect of market size

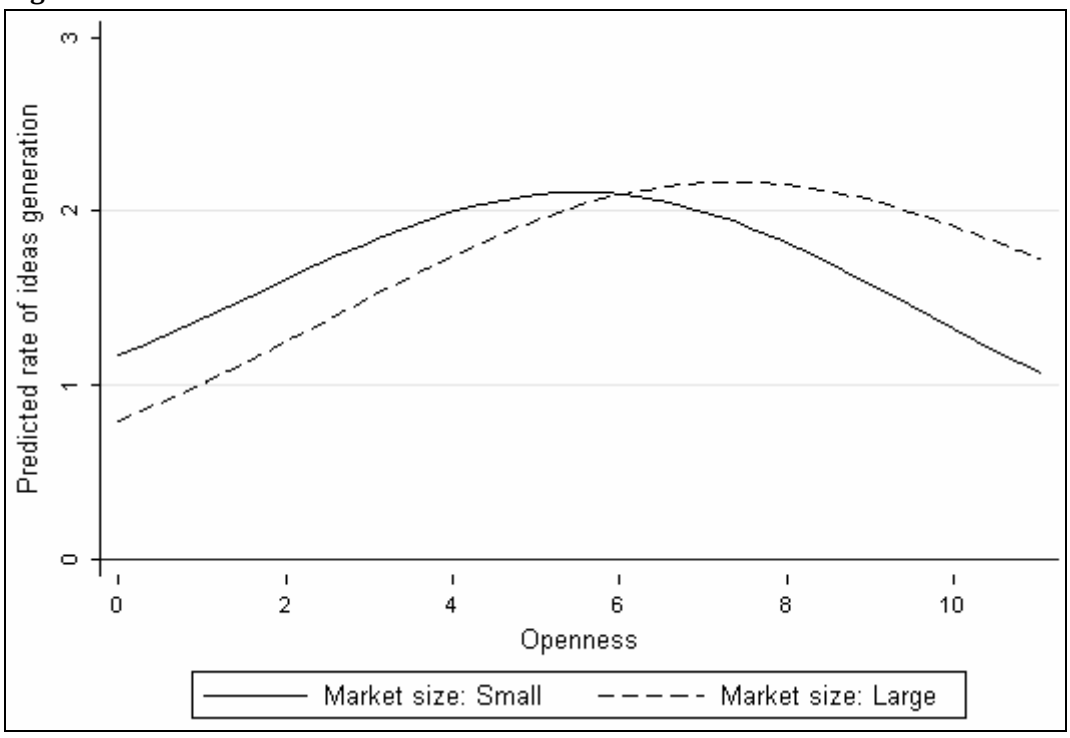
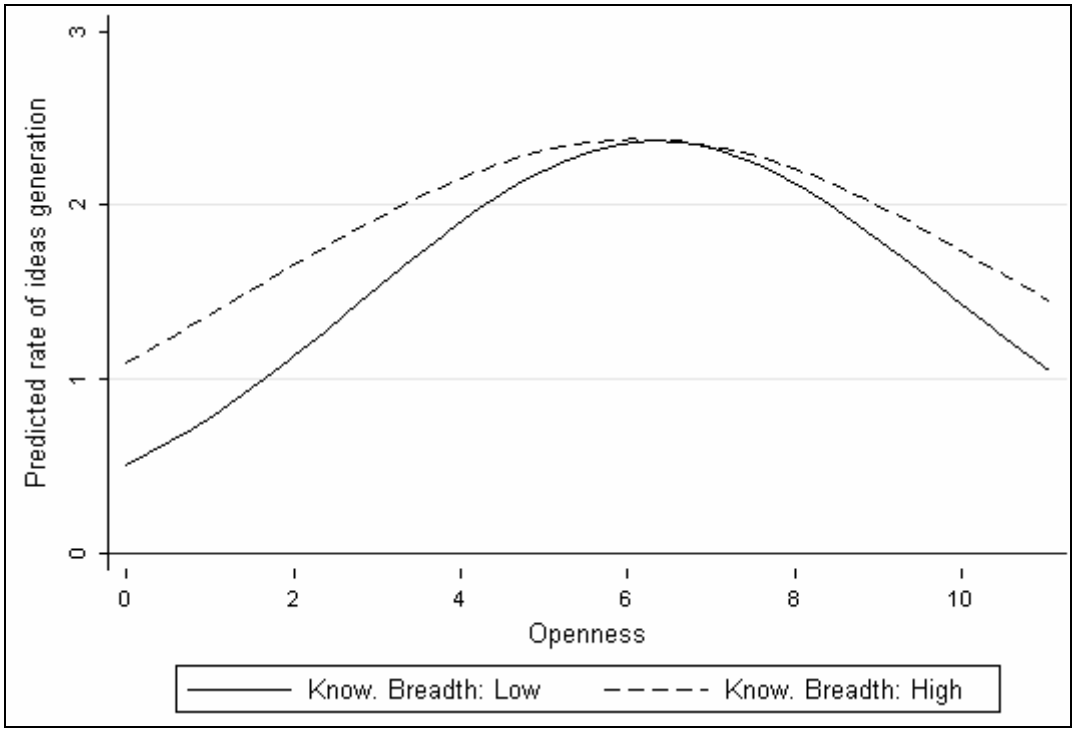


Figure 4 Moderation effect of knowledge breadth



Knowledge breadth: low (mean – 2 standard deviations)
Knowledge breadth: high (mean + 2 standard deviations)