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Managing open innovation at a project level, a dynamic managerial capability perspective

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Abstract

While interest in the open innovation model is still growing, limits to its scope and application are starting to become evident. Empirical evidence has uncovered diminishing returns whereby opening the innovation process to too many actors reduces overall performance. Adopting a dynamic managerial capability perspective on open innovation, we narrow down the level of analysis to the project level to investigate the effect of three dimensions of an open innovation strategy on the type of innovation and project performance. The empirical results, based on a survey of 205 NPD projects in the manufacturing sector in the UK, suggest that the orchestration of the breadth, depth and ambidexterity dimensions of an open innovation strategy do not necessarily produce high performance for NPD projects but is contingent upon whether managers are seeking firm innovation or industry innovation.

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Introduction

The benefits of opening the innovation process to different sources of external information are now well established. Synergies are shown to emerge from such a networked approach and this effect becomes more pronounced as the number and diversity of external parties is increased (Becker and Dietz, 2004; Belderbos *et al.*, 2004; Miotti and Sachwald, 2003; Nieto and Santamaria, 2007; Tether, 2002), with performance benefits for the innovation of new products (Faems *et al.*, 2005; Roper *et al.*, 2008; Tether and Tajar, 2008) as well as innovation performance at the level of the firm (Chesbrough and Crowther, 2006). There is also consensus in the literature about the complementarity between internal R&D and external sources of knowledge (Cassiman and Veugelers, 2006; Grimpe and Kaiser, 2010; Lokshin *et al.*, 2008; Tether and Tajar, 2008)

More recently, research shows that the benefits of an open innovation strategy at a firm level might be offset by several inherent risks. Firstly, there is a risk of dilution of the uniqueness of knowledge resource when firms rely strongly on external sources to foster innovation (Grimpe and Kaiser, 2010). Secondly, a broad degree of openness during the innovation process calls for higher integrative capabilities to assimilate and build upon external knowledge, entailing higher costs (Weigelt, 2009). Finally, apart from potential risks of knowledge misappropriation and spillovers during the course of an open innovation strategy, a broad degree of openness to different types of external party or sources of information exerts an additional pressure on management attention (Ocasio, 1997). Several studies have modelled the limits of open innovation *at a firm level* and observed diminishing returns in innovation performance when the degree of openness to different external sources of information or to different types of external party grows too broad (Grimpe and Kaiser, 2010; Laursen and Salter, 2006; Leiponen and Helfat, 2009; Rothaermel and Deeds, 2006).

This paper addresses two gaps in the open innovation literature. Firstly, we narrow the unit of analysis to the new product development (NPD) project level. While the foregoing literature has been extremely valuable in demonstrating both the value and limits of open innovation, the analytical focus remains primarily at the level of the firm. In one of the few studies of open innovation at the project level, Knudsen (2011) found that those firms which increase

the degree of openness to external partners during the NPD process have lower NPD project performance, worse timing to market and more costly product development projects when compared to the norm in the industry. Therefore, it appears that a more judicious calibration of the degree of openness to external parties, at the *NPD project level*, is important to avoid diminishing return on innovation performance, *at the firm level*. We are therefore interested in the extent to which open innovation can provide benefits to innovation projects and the conditions under which openness can provide advantage.

Secondly, we deconstruct the concept of ‘openness’ to identify three dimensions of open innovation strategy. Previous studies are largely constrained to a single ‘breadth’ dimension, examining the degree of openness from either an inter-organisational relationship or sources of information perspective (Amara and Landry, 2005; Becker and Dietz, 2004; Belderbos *et al.*, 2004; Faems *et al.*, 2005; Laursen and Salter, 2006; Leiponen and Helfat, 2009; Tether and Tajar, 2008). In these studies, the breadth of openness is characterised by the degree of openness to a diverse set of external parties or external sources of information such as suppliers, customers, universities, competitors, private and public research institutes. While there is nothing intrinsically wrong with such an approach, it fails to provide understanding of the underlying dynamic of inter firm relationships when firms open up the innovation process to these different types of external party during NPD projects (Nieto and Santamaria, 2007; Nieto and Santamaria, 2007). In this respect, building from the supply chain networks and strategic management literatures, we conceptualise inbound open innovation strategy as a multidimensional construct consisting of breadth, depth and ambidexterity dimensions (Bahemia and Squire, 2010).

The article proceeds as follows. The first section presents the development of the conceptual model and hypotheses, supporting a dynamic managerial capability perspective on open innovation at a project level. The second section describes the research methodology. Empirical results, based on a sample of 205 NPD projects in the manufacturing sector in the UK, then follow. Next, we proceed with a discussion which analyses the results in light of previous research. Finally, the paper closes with a brief discussion on the limitations of the study and suggestions for future research.

Conceptual model and hypotheses development

There is growing interest in the concept of dynamic managerial capabilities, which sheds light on the importance of managers' strategic decisions to 'build, integrate and reconfigure organizational resources and competences' (Adner and Helfat, 2003). It is argued that differences in managerial decisions in orchestrating assets to generate resources leads to heterogeneity in performance. The concept of dynamic managerial capabilities is an extension to the general organisational capabilities which are broadly defined as capabilities that enable an organisation to 'integrate, build and reconfigure competences' (Teece *et al.*, 1997). Empirical research substantiates that dimensions of dynamic managerial capabilities have a significant bearing on performance (Adner and Helfat, 2003; Kor and Mahoney, 2005; Moliterno and Wiersema, 2007; Sirmon and Hitt, 2009).

This study adopts the dynamic managerial capabilities perspective to test the extent to which the three dimensions of open innovation lead to firm innovation, industry innovation and project performance. In this context, the degree of openness represents a managerial capability to be aligned with the desired outcomes. The three dimensions can all be flexed depending on the goals of the project. Firstly, the breadth dimension of an open innovation strategy is reflected by the degree of openness to different types of external party, such as suppliers, customers, universities, consultants and research institutes during the NPD projects. Secondly, ambidexterity reflects the balance between developing relationships with new external parties and leveraging relationships with longstanding external parties during the NPD project. Finally, the depth dimension characterises the level of involvement with external parties during the NPD project. Our hypothesised model is presented in figure 1 below and is followed by detailed hypothesis development for each of the relationships. We test the relationships between a) breadth and ambidexterity dimensions of an OI strategy and firm innovation b) breadth and ambidexterity dimensions of an OI strategy and industry innovation after controlling for intensity of internal R&D activities, environmental turbulence and level of technology in the industry. Next, we test the extent to which the depth dimension of an OI strategy moderates type of innovation (firm innovation and industry innovation) and project performance relationships after controlling for project size and transformational leadership.

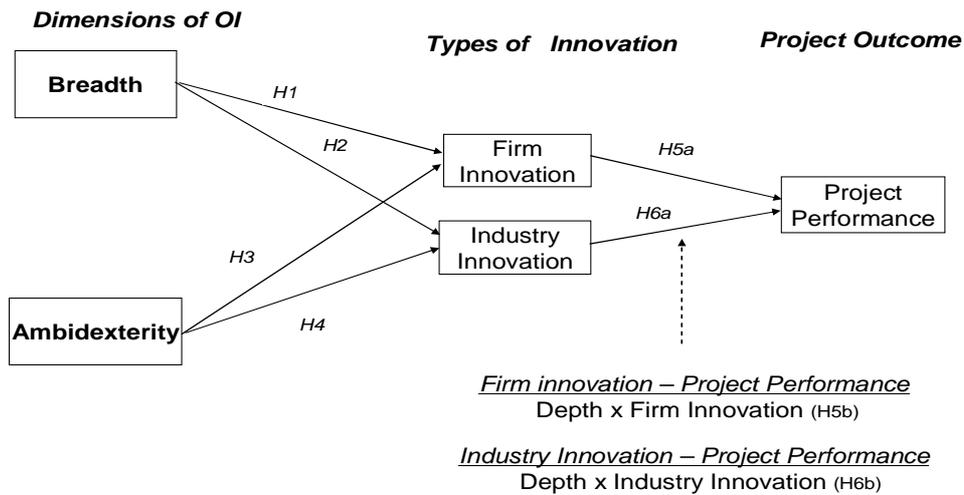


Figure 1

Relationship between breadth of an OI strategy and types of innovation

There is evidence to suggest that scholars have started to examine the concept of ‘openness’ in a more granular manner. Rather than simply conceptualising the innovation model as open or closed, studies have examined the identity of various external parties and the extent to which their effects differ on various outcomes (Faems *et al.*, 2005; Miotti and Sachwald, 2003; Nieto and Santamariaa, 2007; Tether, 2002; Tether and Tajar, 2008). For example, vertical co operations (suppliers, customers) are found to be efficient for innovation which is new to the firm, while co operations with external partners providing science research capabilities (universities, public and private research institutions) are instrumental to bring radical product to the market (Belderbos *et al.*, 2004; Miotti and Sachwald, 2003). According to Tether and Tajar (2008), firms introducing radical innovations are also more likely to engage with specialist knowledge providers, such as universities public and private institutes and consultants, as opposed to those introducing incremental innovations. In a similar vein, Faems *et al* (2005) suggest a portfolio approach to inter firm collaborative arrangements during the innovation process. Their results concur with previous studies reporting that firms, possessing a heterogeneous network of collaborative partners, perform better in terms of the proportion of turnover realized by means of new or improved products.

Despite evidence that openness to different types of external knowledge sources is likely to result in greater innovation, the emergence of diminishing returns offers a more nuanced view (Laursen and Salter, 2006; Leiponen and Helfat, 2009). Diminishing returns may be explained by the cost and time associated when searching multiple channels of information simultaneously and at some point these costs offset any marginal gains to innovation outcomes (Laursen and Salter, 2006). Based on the foregoing arguments, it is expected that the breadth dimension of an OI strategy be curvilinearly related to both firm innovation and industry innovation. Accordingly, we hypothesize:

H1: There is an inverted U relationship between the breadth dimension of an OI strategy and firm innovation.

H2: There is an inverted U relationship between the breadth dimension of an OI strategy and industry innovation

Relationship between ambidexterity of OI and types of innovation

Previous research substantiates the positive relationship between ambidexterity (firm's ability to simultaneously deploy exploration and exploitation strategies) and innovation performance (Raisch and Birkinshaw, 2008; Tushman and O'Reilly, 1996). Those firms simultaneously undertaking exploration and exploitation strategies have higher propensity to achieve both radical and incremental innovation performance. For example, Tushman (2004) reported that firms deploying an ambidextrous capability tend to launch more breakthrough products and reap high performance from existing products too, whereas, (Atuahene-Gima, 2005) found that the interaction between competence exploitation and competence exploration is positively linked to the development of radical innovation.

The concept of ambidexterity is explored both theoretically and empirically from a wide array of perspectives such as flexibility and efficiency (Adler *et al.*, 1999), search scope and depth (Katila and Ahuja, 2002), exploitative and explorative learning (Kang and Snell, 2009), incremental and discontinuous innovations (Benner and Tushman, 2003; Smith and Tushman, 2005), and existing and new alliances partners (Dittrich and Duysters, 2007; Lin *et al.*, 2007). In this paper, we adopt an inter-organisational relationship perspective similar to Lin *et al.* (2007), where cooperation with longstanding (strong ties) and new (weak ties) external parties

exemplifies the exploitation and exploratory dimension of ambidexterity respectively. Social network theory is the primary theory which supports the importance of a heterogeneous network composed of both strong and weak ties relationship. A dual network architecture, where a small core of strong ties is integrated with a large periphery of weak ties, had a positive effect on firm's innovation capability (Capaldo, 2007). Cooperation with existing partners fosters higher level of reciprocity and joint problem arrangements (Uzzi, 1997). Firms often enter into alliances repeatedly with partners from previous ventures due to the reduction of transaction costs as a result of the trust developed (Dyer and Chu, 2003; Gulati, 1995; Walker *et al.*, 1997). In contrast to strong ties theory, the strength of weak ties theory suggests that new possibilities and ideas are more likely to be generated from weak ties than from strong ties (Granovetter, 1973). Repeat collaboration is prone to result from the transfer of the team mental model from previous projects to the subsequent ones, thereby entailing a higher degree of inertia in the team mental model which is likely to stifle the level of creativity (Bettenhausen and Murnighan, 1991). Weak ties offer bridges across cliques providing access to knowledge not available with networks of strong ties. Based on these two perspectives, we suggest that open innovation projects that balance new partners (exploration) with existing partners (exploitation) should provide the greatest gains to innovation.

H3: There is a positive relationship between ambidexterity and firm innovation

H4: There is a positive relationship between ambidexterity and industry innovation

The moderating effect of depth on types of innovation and project performance

Research has shown that high product innovativeness tends to exert additional pressure on project performance, particularly in terms of time to market and R&D budget (Ali *et al.*, 1995). When compared to incremental innovations, radical innovation projects are characterised by greater uncertainties and instability, often leading to unanticipated costs and prolonged development cycle. Hence, we hypothesise that:

H5a: There is a negative relationship between the firm level innovation and project performance.

H6a: There is a negative relationship between the industry level innovation and project performance.

On the other hand, we expect that the negative relationships between type of innovation (firm innovation and industry innovation) and project performance are positively moderated by deep relationship between the firm and those external parties involved in the NPD project. High level of coordination between the firm and external parties is likely to facilitate the problem solving process during NPD projects and thus, improving the overall performance of the NPD project in terms of time to market, technical performance of the product, R&D budget and manufacturing cost of the new product. Extant research from the supply chain networks literature provides empirical support for the importance of developing deep relationship with external partners during the NPD process. Early and high level of integration with suppliers in the new product development process is considered to be among the critical success factors for NPD projects, leading to reduction of cost, shorter development cycle and improved product manufacturability (Bonaccorsi and Lipparini, 1994; Gupta and Wilemon, 1990; Petersen *et al.*, 2005; Ragatz *et al.*, 1997). An early and high level of integration with both customers and suppliers yields to superior performance in the lead time of NPD projects as well as in the design performance of new product (Droge *et al.*, 2004; Jayaram, 2008; Petersen *et al.*, 2005). Besides, other empirical studies have examined the impact of early supplier involvement strategy particularly on radical products: deep level of integration with suppliers is effective in reducing the overall development time for radical innovations (Swink *et al.*, 2006). It is thus hypothesized that a deep relationship between the firm and different types of different external party such as suppliers, universities, research institutes and consultants will positively moderate the negative relationship between types of innovation (firm innovation versus industry innovation) and overall project performance. This leads us to our final two hypotheses:

H5b: Depth of OI positively moderates the negative relationship between firm innovation and project performance

H6b: Depth of OI positively moderates the negative relationship between industry innovation and project performance

Research Methodology

An initial sample of 1480 potential respondents was selected randomly from a commercially available database. The key informant of the study was Engineering Project Managers because they generally have a better knowledge of NPD project performance (Blindenbach-

Driessen *et al.*, 2010). Companies were grouped according to the OECD classification for the level of technology (high technology, medium- high technology, medium – low technology and low technology). Other than job description and industry, project size was also controlled.

The survey was distributed to the respondents either in the format of either a postal or web-based questionnaire. Special attention was paid to the level of personalisation of the survey. For the web based survey, contacting respondents by phone was not only an effective means to create personal contact but also to provide personal assurance of confidentiality of data and non disclosure of email addresses to third parties. Follow ups significantly increased the survey response rate (Cobanoglu and Cobanoglu, 2003). Those respondents, who were initially contacted by phone and agreed to participate in the survey, were contacted again after three weeks in case of non response. Informants were instructed to identify a new product development project which was completed within the last five years and involved at least one external party such as suppliers, customers, universities, competitors, commercial laboratories or private and public research institutes. A total of 211 respondents participated in either the mail or web based survey representing a response rate of 14.2 %. Six questionnaires were discarded for various reasons such as low working experience in the company (less than 6 months) and incomplete responses.

Measurement

Apart for the breadth construct, existing measures were used or were adapted for the remaining constructs. For the breadth measure we followed the approaches of (DeVellis, 2003; Hinkin, 1995) to generate items. These items were generated from the innovation literature, six in-depth case studies at Jaguar Land Rover (UK), discussions with Engineering project Managers from diverse industries and academic experts researching on innovation and supply chain. All items except for the ambidexterity dimension were measured on a seven point Likert scale. Appendix 1 reports the measurement scales and the reliability statistics.

Dependent variables

Project performance was assessed with four items: the respondents had to rate the product development project relative to its goals in terms of technical performance, time to market, unit manufacturing cost and R&D budget (Mishra and Shah, 2009). We measured firm and industry innovation with a scale adapted from (Song and Parry, 1999). Firm level measures

reflect the extent to which the product is new to the firm, while industry level measures reflect the extent to which the product is new to the market.

Explanatory variables

In the open literature, the majority of studies adopt a nominal scale where various sources of information are scored 1 if used and 0 if not used for the purposes of innovation (Grimpe and Kaiser, 2010; Laursen and Salter, 2006; Leiponen and Helfat, 2009; Mol and Birkinshaw, 2009; Oerlemans and Knobens, 2010). This operationalisation of the breadth construct entails several limitations. All of these studies are based on the Community Innovation Survey (CIS) questionnaire and hence, they were constrained to measure breadth as a nominal scale at a firm level. Nominal scales are restrictive as it limits respondents choice to two categories (0 for involvement and 1 for no involvement) and represent the simplest level of measurement generated for classification purposes only (Venkatraman and Grant, 1986). Further theory development is hindered due to the fact a nominal measure remains deficient of the causal explanation of the theoretical domain of the construct (Venkatraman and Grant, 1986). To overcome this limitation, a continuous scale was developed for measuring the breadth dimension of an OI strategy at a project level.

There were three stages in the development process of the measurement scale for the breadth construct (DeVellis, 2003). Initially, items for the construct were generated by means of a deductive approach to scale development and to this effect, insight into the conceptual domain was gained from an in depth literature review (Hinkin, 1995). In the second stage of the scale development process, the underlying theoretical justification for opening up to a broad range of different types of external party was subjected to further content validity assessment by respondents at Jaguar Land Rover and sixteen practitioners from different industries in the manufacturing sector in the UK. The third stage of the scale development process for the breadth measure sets the boundary of the theoretical domain of the construct to limit the items from overlapping into 'unintended domains' (DeVellis, 2003). In this respect, the items for the breadth measure were aligned to specific activities of the new product development project context to benefit the project unit of analysis of the study.

In the survey questionnaire, respondents had to indicate first the different types of external party (suppliers, individual innovator, customers, crowd sourcing, competitors, consultants, universities, government research organizations, commercial laboratories, private research

institutes, and open innovation intermediary) involved in their NPD projects. Six items were developed to capture the theoretical domain of the breadth construct and respondents were asked to indicate on a scale 1-7 the number of different types of external party involved in their NPD projects for each of these items.

The ambidexterity dimension of an OI strategy used an ordinal scale was used to calculate the percent of new partners. Following Lin *et al.*(2007), we model ambidexterity as the total number of new external partners divided by the total number of external parties (longstanding and new) involved in the NPD project. Because ambidexterity examines the balance between exploration and exploitation, yet the ‘point of balance’ is unknown, we use the quadratic term of this measure. The quadratic terms enables us to test the inflection point where the benefits of exploration start to diminish and the benefits of exploitation start to become more important.

Following Hardy *et al.* (2003), we conceptualise depth as the level of involvement with external parties. A high level of involvement, indicating a deep relationship, is composed of three dimensions: 1) deep pattern of interaction 2) strong coalition structure (i.e. work as partners to carry out particular activities) 3) pattern of information sharing among collaborating partners. The closest measure in the literature which meets the three aforementioned dimensions of a deep relationship is an inter-functional integration measure which we adapt to the context of new product development (Garcia *et al.*, 2008; Kahn, 1996; Pinto and Pinto, 1990).

Control variables

We include the following control variables: internal R&D intensity, transformational leadership, project size, industry, technological and market turbulence. Transformational leadership was measured using the Global Transformational Leadership Scale (Carless *et al.*, 2000). Project size was measured by the number of people involved in the NPD project including internal and external parties. The measures for technological and market turbulence were similar to those of Jaworski and Kohli (1993). Patents were used as a proxy for internal R&D intensity similar to several studies in the innovation literature (Carrington, 2003; Ernst, 2001; Lin, 2005). According to Griliches (1990), using patents data as a proxy for internal R&D remains a valid exercise given the strong empirical relationship between patents and

R&D expenditures. We based the measurement of patents on the patents indicator of the appropriability measure developed by Levin *et al.* (1987).

Non response bias and common method bias

Following the completion of the survey, a telephone follow up was conducted randomly across thirty non respondents to check for non response bias. The T test shows that there was no significant difference between respondents and non respondents. In addition, Harman's single factor test was used to test for the presence of common variance method bias. In the event of a high degree of common method variance, a single factor would emerge from a factor analysis of the entire set of distinct variables (Podsakoff and Organ, 1986). The items for all constructs of the model were loaded into an EFA and the unrotated factor solution was examined to determine the number of factors necessary to account for the variance in the model. As a result, all the twelve factors of the model were extracted as twelve distinct factors with an Eigen value above 1.

Measurement model, convergent and discriminant validity

An EFA was conducted on all items to reduce the large number of observed variables to a smaller subset of factors to inspect the structure of the factors (Hair *et al.*, 2006). Although the majority of items loaded on the proper constructs, two items from market turbulence, one item from technological turbulence and one item from industry innovation were dropped as the factor loadings were below the threshold of .50 (these items are identified with * in Appendix 1). Firm innovation and industry innovation emerge clearly as distinct constructs with no overlapping items. The Eigen values for all factors after rotation were above the cut off point (1), indicating the amount of variation in the total sample accounted for by each factor is satisfactory. Next, a CFA was run to examine the fit of the measurement model, convergent and discriminant validity. Overall the fit of the measurement model was assessed with Normed Fit Index (NFI), Comparative Fit Index (CFI) and Incremental Fit Index (IFI). Results of the measurement model provide a satisfactory model fit with the values of CFI (.93), TLI (.92), IFI (.93) exceeding the critical level of .90 for a good model fit (Byrne, 2001). Satisfactory model fits are further indicated by RMSEA less than .05 and a chi square/df ratio of 1.61.

Additionally, factor loading, average percentage of variance extracted derived from the CFA and reliability scores of the constructs were used to estimate convergent validity. First, examination of the factor loading show that all items loaded significantly on their respective factors and the standardised loading was larger than the minimally accepted level of .50 for all constructs. Additionally, all constructs exhibited an average variance extracted (AVE) above .50 which is the criteria for convergent validity (Hair *et al.*,2006). Second, the reliability of the measures was evaluated using Cronbach’s alpha. The value of Cronbach’s alpha is greater than the cut off value of .70 suggested by Bryman (2001) for the majority of constructs except for project performance, indicating good reliability. According to Cortina (1993), a Cronbach’s alpha of .60 would be considered acceptable for measures with less than six items: the measurement scale for project performance consisted of only four items and the Cronbach alpha was .64.

Furthermore, an examination of Figure 2 reveals that discriminant validity among constructs is considered to be satisfactory as the AVE (diagonal elements) is greater that the square correlation (off diagonal elements) (Hair *et al.*, 2006).

Construct	1	2	3	4	5	6	7	8
1 Breadth	0.57							
2 Depth	0.08	0.53						
3 Internal R&D	0.07	0.02	0.72					
4 Industry Innovation	0.00	0.00	0.13	0.50				
5 Firm Innovation	0.14	0.03	0.09	0.14	0.66			
6 Project Performance	0.00	0.01	0.01	0.01	0.01	0.31		
7 Leadership	0.00	0.09	0.00	0.03	0.02	0.01	0.78	
8 Technological Turbulence	0.05	0.02	0.00	0.13	0.07	0.06	0.02	0.62
9 Market Turbulence	0.02	0.01	0.01	0.04	0.01	0.02	0.10	0.00

Figure 2

Results

Figure 3 reports means, standard deviations and correlations for all variables included in the study. 30.73 % of companies were from the high technology industry, 44.39 % were from high medium technology industry while 6.34 % and 18.54 % were from the medium low technology and low technology industry respectively. This high concentration is in line with the specific characteristics of the manufacturing sector in the UK which is orientated towards high value and knowledge intensive manufacturing.

	1	2	3	4	5	6	7	8	9	10
Mean	2.1	4.9	34.9%	3.6	4.3	3.9	4.3	5.4	4.5	4.4
Standard Deviation	0.9	1.1	31.8%	1.5	1.4	1.8	1.2	1.1	1.2	1.3
1 Breadth		.27(**)		.24(**)		.31(**)				.19(**)
2 Depth				.14(*)		.15(*)		.26(**)		
3 Exploratory				.20(**)	.21(**)	.33(**)				
4 Internal R&D					.33(**)	.28(**)				
5 Industry Innovation						.25(**)				.29(**)
6 Firm Innovation										.18(**)
7 Project Performance								.14(*)	.22(**)	
8 Leadership										
9 Market Turbulence										.44(**)
10 Technological Turbulence										

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Figure 3

Hypotheses 1 and 2

A hierarchical multiple regression was run to test the effect of breadth and ambidexterity dimensions of an OI strategy on firm innovation. All independent variables were mean centred to reduce possible multicollinearity between the main effects and the interaction terms (Aiken, 1996). In addition to the direct relationships between a) breadth dimension of an OI strategy and firm innovation b) exploratory dimension of an OI strategy and firm innovation, nonlinear relationships were tested by using a linear and squared term for both breadth and exploratory constructs. The squared term is included to test for the proposed inverted U-shaped relationship between breadth and firm innovation. An inverted U relationship is supported if the coefficient of the linear relationship variable is positive while the coefficient for the squared term is negative (Aiken, 1996). Consistent with our predictions, the result supports an inverted U-shaped relationship between breadth and firm innovation (H1) as the linear effect is positive ($b = .447$; $p < .001$) while the quadratic effect is negative ($b = (.251)$; $p < .01$). This implies that opening up to many types external parties (breadth construct) has a positive effect on firm innovation up to a point when greater openness to different external parties leads to diminishing returns on firm innovation.

Dependent variable: Firm Innovation

	Model 1	Model 2	Model 3	Model 4
	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>
<i>Control variables</i>				
High Technology Industry	0.14	.160*	.166*	0.15
High Medium Technology Industry	0.08	0.11	0.12	0.12
Technological Turbulence	0.13	0.09	0.07	0.06
Market Turbulence	0.06	0.06	0.09	0.09
Internal R&D	.279***	.163*	.151*	.147*
<i>Main Effects</i>				
Breadth		.246***	.447***	.441***
Exploratory		.288***	.260***	.398*
Breadth x Breadth			- 0.251**	- .249**
Exploratory x Exploratory				-0.15
R Square	0.12	0.25	0.28	0.28
Adjusted R Square	0.10	0.23	0.25	0.25
Change in R Square	.120***	.134***	.023**	0.00

* p < .05 **p < .01 ***p < .001

Figure 4

Additionally, a curve estimation was run on the data, prior to mean centering, to capture the precise inflection point when diminishing returns set in. Figure 5 shows that diminishing returns on firm innovation occur at the point when firms open up to more than six types of external parties out of eleven. It is to be noted that the breadth construct was measured on a Likert scale of 1- 7 and scale 4 represents openness to a maximum of six types of external parties (Appendix 1).

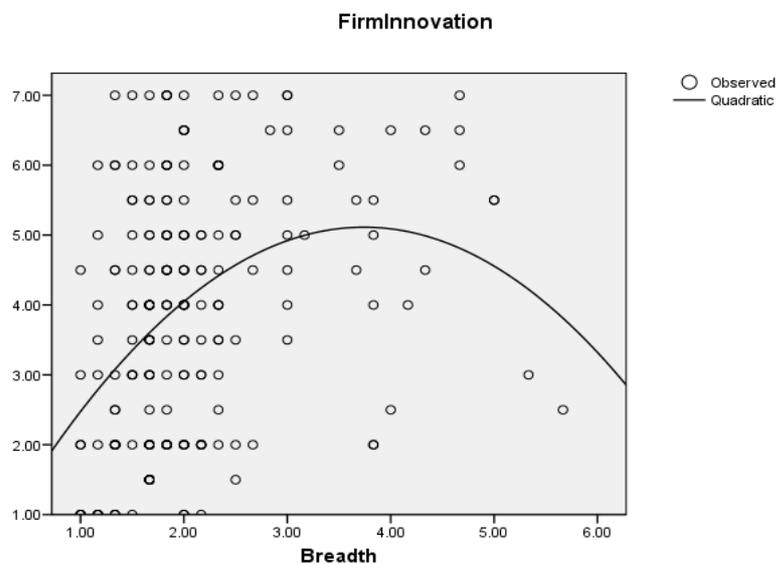


Figure 5

We also used a quadratic term to test H_3 . An ambidextrous relationship will be found if the linear exploratory variable is positive while the coefficient for the quadratic term is negative (Aiken, 1996). Contrary to our predictions, H_3 stating that there is an inverted U relationship between exploratory dimension and firm innovation is not supported suggesting that the ambidexterity of an OI strategy (mix of longstanding and new external partners) does not have any significant effect on firm innovation. On the other hand, there is a direct linear relationship between the exploratory dimension of an OI strategy and firm innovation ($b = .260$; $p < .001$), suggesting that the more firms open up to new external parties, the better the level of firm innovation. We also find moderate support in Model 4 for the importance of internal R&D for firm innovation ($b = .147$; $p < .05$).

Hypotheses 3 and 4

The second hierarchical regression model tests the relationship between breadth and ambidexterity dimensions of an OI strategy and industry innovation and the results are illustrated in Figure 6. First, counter to our predictions, the breadth dimension of an OI strategy does not have any significant effect on industry innovation (H_2). The significant relationship between internal R&D and industry innovation ($b = .298$; $p < .001$) coupled with a non significant linear relationship between breadth and industry innovation highlight the importance of internal R&D for the development of industry innovation particularly in an environment which is technologically turbulent.

H_4 is partially supported as we find a significant linear but not a non-linear relationship between ambidexterity and industry innovation. Similar to the previous model, this suggests that greater exploration provides better returns to innovation without significant diminishing returns (exploitation). Examining the control variables, the level of technological turbulence ($b = .321$; $p < .001$) and internal R&D ($b = .310$; $p < .001$) are significantly correlated with industry innovation. As indicated in the previous section, the relationship between internal R&D and firm innovation is weaker for firm innovation ($b = .147$; $p < .05$) when compared to industry innovation, signalling a different dynamic between firm innovation and industry innovation.

Dependent variable: Industry Innovation

	Model 1	Model 2	Model 3	Model 4
	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>
<i>Control variables</i>				
High Technology Industry	-0.12	-0.14	-0.14	-0.12
High Medium Technology Industry	-0.08	-0.09	-0.09	-0.09
Technological Turbulence	.290***	.307***	.319***	.321***
Market Turbulence	-0.05	-0.05	-0.06	-0.06
Internal R&D	.304***	.298***	.304***	.310***
<i>Main Effects</i>				
Breadth		-0.10	-0.20	-0.19
Exploratory		.154*	.168*	-0.06
Breadth x Breadth			0.12	0.12
Exploratory x Exploratory				0.24
R Square	0.18	0.21	0.22	0.22
Adjusted R Square	0.16	0.18	0.19	0.19
Change in R Square	.181***	.031*	0.01	0.01

* p < .05 **p < .01 ***p < .001

Figure 6

Hypotheses 5 and 6

Hypotheses 5b and 6b stated that the depth dimension of an OI strategy would positively moderate the negative relationships between a) firm innovation and project performance (*H5a*) b) industry innovation and project performance (*H6a*). Our results in Figure 8 provide partial support for these hypotheses. The hypothesized direct negative relationships between both types of innovation and project performance are not supported (*H5a* and *H6a*), however, the depth of OI positively moderates firm innovation and project performance (*H5b*) ($b = .186$; $p < .01$), as illustrated in the interaction model in Figure 7. As for the control variables, project size is negatively correlated with both firm innovation ($b = .253$; $p < .001$) and industry innovation ($b = .245$; $p < .001$) while transformational leadership is moderately correlated with firm innovation ($b = .153$; $p < .05$) and industry innovation ($b = .138$; $p < .05$).

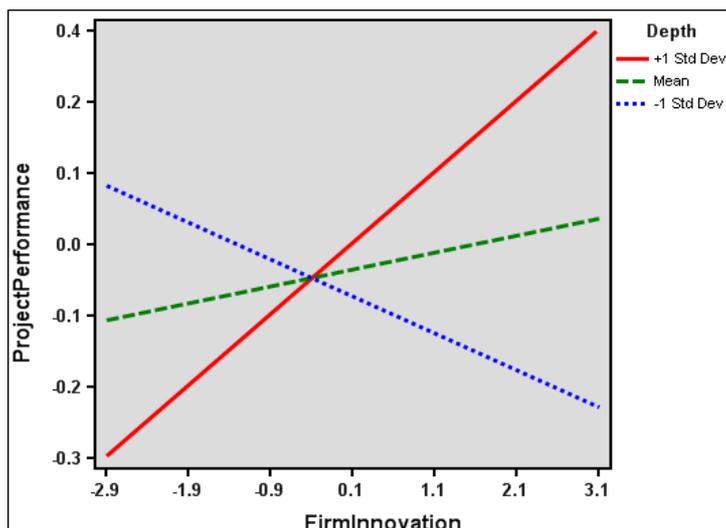


Figure 7

Dependent variable: Project Performance

	Model 1	Model 2	Model 3
	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>
<i>Control variables</i>			
Project Size	(.239)***	(.247)***	(.253)***
Transformational Leadership	.155*	.144*	.153*
<i>Main Effects</i>			
Firm Innovation		0.07	0.07
Depth		0.02	0.02
<i>Interaction Effect</i>			
Firm Innovation x Depth			.191**
R Square	0.08	0.08	0.12
Adjusted R Square	0.07	0.07	0.10
Change in R Square	.07***	0.00	.04**
<i>Control variables</i>			
Project Size	(.239)***	(.242)***	(.245)***
Transformational Leadership	.155*	.135*	.138*
<i>Main Effects</i>			
Industry Innovation		0.07	0.06
Depth		0.03	0.03
<i>Interaction Effect</i>			
Industry Innovation x Depth			0.04
R Square	0.07	0.08	0.08
Adjusted R Square	0.06	0.06	0.06
Change in R Square	.076***	0.01	0.00

* p < .05 **p < .01 ***p < .001

Figure 8

Discussion

This present study was motivated by the recent emergence of studies identifying potential limits to inbound open innovation *at the firm and project levels* (Knudsen and Mortensen, 2011; Laursen and Salter, 2006; Leiponen and Helfat, 2009). These limits were reflected by diminishing returns on performance which set in when firms open up the innovation process to too many different types of external source of knowledge *at a firm level* (Laursen and Salter, 2006; Leiponen and Helfat, 2009). To complement our understanding of the limits of an open innovation strategy *at a firm level*, we narrowed the analytical lens to the level of NPD projects, arguing that diminishing returns, *at a firm level*, are likely to result from the long run cumulative effects of opening up the innovation process too far *at the project level*. Following the tradition of the open innovation literature, we adopt an inter organisational relationship perspective and define openness along the breadth dimension (degree of openness to diverse range of external parties) (Knudsen and Mortensen, 2011; Oerlemans and Knobens, 2010). We further refine this view of openness by conceptualising an inbound innovation strategy as a multidimensional construct consisted of two further underlying dimensions: depth and ambidexterity. These additional dimensions are crucial to our understanding of open innovation as they represent managerial levers that can be manipulated depending on the desired outputs of the project.

Our results provide empirical evidence that the orchestration and integration of the breadth exploratory and depth dimensions of an OI strategy during NPD projects represent a managerial dynamic capability, leading to the emergence of firm innovation and high project performance for firm innovation. As anticipated, the capability of managers to open their NPD projects to different types of external party has a highly stimulating effect on firm innovation. The mix of different types of partners is likely to release synergies in the innovation process (Tether 2002, Tether and 2004; Miotti and Scahwald, Faems et al 2005; Nieto and Santamaria, 2007, Amara and Landry). Furthermore, the limits of open innovation *at a project level* is also perceptible from the diminishing returns on firm innovation which set in when firms opens up simultaneously to more than six different types of external parties. The accurate orchestration of the breadth dimension of an OI strategy by managers in order to avoid diminishing returns is of critical importance for the generation of firm innovation.

Although, it was postulated that the ambidexterity dimension of an OI strategy (mix of strong and weak ties relationships) would have an effect on firm innovation, our results display

better fit with the strength of weak ties theory where the exploratory dimension of an OI strategy comes to the forefront. Instead of an inverted U relationship between exploratory dimension of OI and firm innovation, we found a direct positive linear relationship. The capability of managers to integrate new external parties the innovation process appears also to be highly influential for firm innovation as it reduces substantially the degree of lock-in effect and inertia in the mental team model which is likely to stifle the level of creativity (Bettenhausen and Murnighan, 1991). Finally, we also found that the capability of managers to develop deep relationship with external parties involved in the NPD project is equally important for firm innovation as shown by the positive moderating effect of the depth dimension of an OI strategy and project performance.

Additionally, the results present some surprising and unexpected results that raise further questions about the limits to adoption an open innovation strategy at the project level, particularly for *industry innovation*. Contrary to our expectations, we found a contrast in the dynamic for managing *firm innovation* and *industry innovation*. Openness to a diverse range of external parties (breadth dimension of an OI strategy) does not have any bearing on industry innovation. In contrast, the capability of managers to forge relationships with new external parties (exploratory dimension of an OI strategy) as well as investing into internal R&D appears to be the mechanisms through which industry innovation is generated. Arguably, this effect is attributable to the fact that the need for a unique knowledge resource tends to be higher for industry innovation, thus explaining the importance of in house R&D activities, and to a lesser extent, the need for interaction with new external parties. Our results suggest that for both firm innovation and industry innovation, internal R&D mitigates the risk of the dilution of the uniqueness of knowledge resource although internal R&D appears to remain the primary conduit for industry innovation. Finally, we found that the capability of managers to develop deep relationship with those external parties involved in the NPD projects does not moderate the relationship between industry innovation and project performance. Understandably, the high significance of internal R&D for industry innovation suggests that the success of the NPD project is more likely to be influenced by the dynamic of the internal NPD project team.

Tying our results to the initial dynamic managerial capability framework, a higher level approach, whereby a contingency theory is nested within a dynamic capabilities framework, provides better insights when managing an open innovation strategy at a project level. The

benefits of orchestrating assets in a contingent way within the umbrella of dynamic managerial capability and resource management logics are recently emerging in the strategic management literature (Sirmon and Hitt, 2009). In point of fact, our results suggest that the orchestration of the three dimensions of an OI strategy alone will not produce high performance unless managers orchestrate these dimensions of an OI strategy in different ways for *firm innovation* and *industry innovation*. As a result of the inherent risks of an open innovation strategy at a project level, success rests on the capability of managers to build, orchestrate and integrate the breadth, exploratory and depth dimension of an OI strategy as well as the internal R&D activities in reaction to the main contingent factor i.e. the types of innovation. The innovation process for products which are first introductions for the firm and those which are industry first introductions is fundamentally different. The appropriate OI strategy that befits each type of innovation seems anything but universal whereby industry innovation requires a different learning path from firm innovation.

Limitations and future research

The point of departure of the study was a dynamic managerial capability perspective; however our results find empirical support for a contingency approach under the umbrella of dynamic managerial capability. This represents a promising avenue for managing an open innovation strategy at a project level. The results of the study have gone beyond our initial expectations as the differences between firm innovation and industry innovation were fundamental. In this respect, although the managerial implications are comprehensive in terms of implementing an OI strategy at a project level for *firm innovation*, they remain, to some extent, limited for *industry innovation*. Our results pave the way for future lines of inquiry to uncover other underlying factors which would improve the explanatory power of the model for industry innovation from both a contingency and dynamic managerial capability perspectives. Additionally, as examples of further research, the contingency theory of open innovation would be enhanced by exploring effective ways for managers to orchestrate the breadth, depth, exploratory dimensions of an open innovation strategy at different stages of the new product development process for *firm innovation* and *industry innovation* respectively.

Appendix 1 Questionnaire Items

Breadth Dimension $\alpha = .89$ (7 item scale: 0 External parties = 1, 11 External Parties = 7)

The previous question (Refer to Note 1) lists eleven possible types of external parties which can be involved during a New Product Development (NPD) project. Of these eleven types of external parties, how many were used in the following activities during this NPD project?

	0	1-2	3-4	5-6	7-8	9-10	11
To generate new ideas and to explore opportunities	1	2	3	4	5	6	7
To gain access to new technologies, expertise and know how	1	2	3	4	5	6	7
To complement our in house research and Development capability	1	2	3	4	5	6	7
To develop the concept of the new product and/or any related process	1	2	3	4	5	6	7
To design and engineer the new product and/or any related process	1	2	3	4	5	6	7
To develop and test the prototypes of the new product and/or any related process	1	2	3	4	5	6	7

In our survey, we asked the respondents to tick 1 if the following external parties were involved in the NPD projects:

Suppliers, any Individual innovator, entrepreneur, start up or spin off, customers, call for ideas from members of the general public (i.e. crowd sourcing), competitors, consultants (i.e. research, design, technical, product engineering, marketing), universities or other higher education institutes, government research organizations, commercial laboratories, private research institutes, open innovation intermediary: an agency which connects companies with a broad range of external experts

Depth Dimension $\alpha = .84$ (7 item scale: 1 = Strongly Disagree, 7 = Strongly Agree)

Our firm and the external parties helped one another to accomplish their tasks in the most effective way

Our firm and the external parties tried to achieve goals jointly

Our firm and the external parties shared ideas, information and/or resources

Our firm and the external parties took the project's technical and operative decisions together

There was open communication between our firm and the external parties

Ambidexterity Dimension (Ordinal Scale)

Please estimate the total number of external organisations involved in this New Product Development (NPD) project _____

Please estimate the total number of new external organisations involved in this New Product Development (NPD) project. By 'new', we mean they should not have been involved in previous projects _____

Industry Innovation $\alpha = .79$ (7 item scale: 1 = Strongly Disagree, 7 = Strongly Agree)

This product relied on technology that had never been used in the industry

This product caused significant changes in the whole industry

This product was one of the first of its kind to be introduced in the market

This product was highly innovative and totally new to the market

Firm Innovation $\alpha = .79$ (7 item scale: 1 = Strongly Disagree, 7 = Strongly Agree)

The product class itself was totally new to the company *

The nature of the manufacturing process was totally new to our company

The technology required to develop the product was totally new to us

Project Performance $\alpha = .64$ (7 item scale: 1 = Much Worse, 7 = Much Better)

Technical performance relative to specifications

Time to market

Unit manufacturing cost

R&D budget

Patents $\alpha = .83$ (7 item scale: 1 = Very Ineffective, 7 = Effective)

How effective were the following means of protecting the innovation advantage for this new product and/or process related to this product?

Patents to prevent duplication

Patents to secure royalties income

Transformational Leadership $\alpha = .96$ (7 item scale: 1 = Strongly Disagree, 7 = Strongly Agree)

The manager communicated a clear and positive vision of the future.

The manager treated staff as individuals, supported and encouraged their development

The manager gave encouragement and recognition to staff

The manager fostered trust, involvement and co-operation among team members

The manager encouraged thinking about problems in new ways and questioned assumptions

The manager was clear about his/her value and practiced what he/she preached

The manager instilled pride and respect in others and inspired the team by being highly competent

Market Turbulence $\alpha = .72$ (7 item scale: 1 = Strongly Disagree, 7 = Strongly Agree)

In our kind of business, customers' product preferences change quite a bit over time

Customers tend to look for new products all the time

We are witnessing demand for our products and services from customers who never bought them before *

New customers tend to have product-related needs that are different from those of our existing customers

We cater to much the same customers that we used to in the past *

Technological Turbulence $\alpha = .86$ (7 item scale: 1 = Strongly Disagree, 7 = Strongly Agree)

The technology in this product area is changing rapidly

Technological changes provide big opportunities in this product area

A large number of new product ideas in this area have been made possible through technological breakthroughs in our industry

Technological developments in this product area are rather minor

It is very difficult to forecast where the technology in this product area will be in the next five years *

* Deleted items

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