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Openness in product and process innovation

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Abstract: Open innovation has generally been seen as an important driver of improved efficiency and effectiveness in product and/or service innovation. This chapter extends these focal areas to include process innovations – generally organizational innovations aimed at improving the nature of organizational value adding and factor transformative systems. In this study we assess the impact of openness on products, services and processes, drawing on a large-scale sample of Australian firms. We find that open innovation models are useful for firms seeking to innovate in processes, as well as products and services. However, we find that openness to external information sources may, after a time, lead to decreasing marginal returns as measured by innovation performance. We also observe that, within our sample, the proposed complementarities between internal and external knowledge sources are generally only evident as precursors to the introduction of new products and services, and may not be as beneficial in stimulating process innovations. We also show that investment in absorptive capacity has a declining marginal effect on the innovation performance of new processes, but not on the introduction of new products and services.

Keywords: Open innovation, product innovation, technological process innovation, organizational process innovation.

Introduction

Although the market and economic impacts of process innovation are often considered as significant as the introduction of new products/services, process innovation is often downplayed in the innovation literature at large (Ettlie, 2006; Hatch and Mowery, 1998; Reichstein and Salter, 2006). This might be a result of process innovation's attributes that are generally considered to be somewhat 'diffuse and elastic' (Reichstein and Salter, 2006: 655), and evident only within the confines of the 'black box' of the firm (Damanpour and Gopalakrishnan, 2001; Rosenberg, 1982), and hence hard to measure.

This paucity of research on the impacts of process innovation extends to the nascent open innovation literature. Open innovation is an emerging innovation paradigm that is increasingly explored. Consistent with the wider innovation literature, the measures of innovation performance most commonly used in the empirical research on open innovation are related to product innovation output (e.g. Bahemia and Squire, 2010; Grönlund et al., 2010; Laursen and Salter, 2006; Lichtenthaler, 2008). Process innovation, as another primary form of innovation, has been largely ignored in terms of its relevance to openness (Reichstein and Salter, 2006).

Our study attempts to fill this gap in the open innovation literature through an empirical examination of the impacts of openness on innovation in an organization's operational and managerial processes, and also on product innovation. By doing this, this study seeks to provide theoretical understanding, empirical evidence and practical implications regarding such a critical issue within open innovation research.

Literature Review

Product and process innovation

Innovation consists of two dynamic outcomes — changes in the specific products/services offered to the customers or clients, and changes to the mode by which they are created and delivered (Damanpour and Gopalakrishnan, 2001). These two forms of change correspond to 'product' innovation and 'process' innovation respectively (Tidd et al., 2001: 6), with product innovation focusing on *what* is produced, while process innovation concerns itself with *how* existing products/services are produced (Edquist et al., 2001).

Product innovation can be used to strategically differentiate an organization's product offerings in the marketplace, thereby satisfying market demands, building customer loyalty, and improving firm performance (Brown and Eisenhardt, 1995; Damanpour, 1991; Damanpour and Gopalakrishnan, 2001; Edquist et al., 2001). Process innovation denotes a process of renewal within organizations. This form of innovation has also been found to be an important driver of firm performance and an essential strategic means to improve a firm's competitive position (Hatch and Mowery, 1998; Reichstein and Salter, 2006).

Process innovation typically encompasses both technological and organizational

dimensions (Edquist et al., 2001; Reichstein and Salter, 2006). The distinction between these sub-categories emerges from whether process innovation involves technological elements or only relates to the coordination of human resources or other organizational systems (Edquist et al., 2001). Typically, technological process innovation takes the form of improvements in operating procedures (Brown and Karagozoglu, 1989; Damanpour, 1991), consisting both of enhanced manufacturing operations (Davenport, 1993; Reichstein and Salter, 2006), and improved service operations (Damanpour and Gopalakrishnan, 2001).

Technological changes in products and operations might concurrently lead to other changes in organizational processes with new administrative procedures, new strategies and new organizational structures, leading to the form of organizational and managerial process innovation (Ettlie, 2006; Ettlie and Reza, 1992).

The paradigm of open innovation

Open innovation, a recently popularized model that contrasts the traditional, closed way to conduct innovation, has been viewed as a new source of competitive advantages in the current business context (Chesbrough, 2003a, 2003b). Firms pursuing it are seen to employ the “use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand markets for external use of innovation, respectively” (Chesbrough, 2006: 1).

Recent research has empirically extended literature exploring issues relating to the open vs. closed innovation view (e.g. Christensen et al., 2005; Laursen and Salter, 2006; Lichtenthaler, 2008). Other scholars have conducted comprehensive reviews of important research in this field, assessing the emerging open innovation paradigm and its future directions (e.g. Giannopoulou, et al., 2010; Huizingh, 2011).

However, in addition to the advocates of open innovation, there are also some critics. Some of them challenge whether open innovation, which has been widely recognized as a new paradigm for innovation and R&D management, signifies some novel organizational phenomenon or just a re-packaging of the old theories relating to R&D externalization and R&D collaboration (Trott and Hartmann, 2009). Other researchers such as Lazzarotti and Manzini (2009) also investigated the applicability of the open innovation modes in practice and argued that, in some cases, total openness might be not the most suitable option, but rather different degrees and different ways of openness, and even some combination of openness and closed

arrangements, should be employed according to the firm's current innovation state.

These questions regarding applicability and generalizability point to some gaps in the current research on open innovation. Chesbrough's (2003a) early comparison between closed and open models mainly focused on the specific cases of large or leading industrial corporations in high technology industries, such as AT&T, IBM and Microsoft. The effectiveness of this new paradigm has been later examined in different contexts by Chesbrough and other researchers, such as for SMEs (e.g. Lee et al., 2010; van de Vrande et al., 2009) and in other industries (e.g. Chesbrough and Crowther, 2006; Chiaroni et al., 2010; Laursen and Salter, 2006). Nevertheless, the impacts of openness on the performance of fundamental forms of innovation, especially process innovation, have not been adequately investigated previously.

In order to address this important gap in the existing literature, this paper seeks to assess open innovation issues in the context of process innovation as well as product innovation. We then explore innovation performance of process innovation in two subareas — namely in the development and utilization of new technological processes (especially in terms of operational processes) and in the development and adoption of new organizational and managerial processes.

Theoretical Framework & Hypotheses

Open innovation's principles and fundamental ideas draw on rich traditions from prior research into R&D externalization and environmental interaction (Christensen et al., 2005; Grönlund et al., 2010). The primary sources of antecedent theories for open innovation can be summarized according to the three main dimensions below. These dimensions also form the foundation for the theoretical framework of our research.

The first important literature relates to external knowledge networks and related technology-sourcing transactions, including external collaboration, process outsourcing, external technology acquisition, licensing, and technology commercialization (Jones et al., 2001; Mitchell and Singh, 1996; Sen and Egelhoff, 2000). Such specific means to interacting with the external environment have been recently contextualized as the main dimensions of a firm's strategic approaches to openness (Lichtenthaler, 2008; Rasmussen, 2007).

The second important body of literature builds on the role of external knowledge inflows and outflows as facilitators of innovation, through a wide range of external

knowledge sources, such as customers, suppliers, competitors and research institutions (Arora and Gambardella, 1990; von Hippel, 1988). Recently, it has been recognized that the breadth of external knowledge and technology sources is important, with this diversity acting as a driver of a firm's internal growth, value creation processes and innovation performance (Grönlund et al., 2010; Laursen and Salter, 2006; Lichtenthaler, 2008). The extent of accessing and utilizing external knowledge sources comprises one of the central dimensions that indicate the degree of openness — the external search breadth by Laursen & Salter's (2006) study. It implies that those firms with higher numbers of external sources tend to be more 'open' than others in some sense.

The third stream of the antecedent research regarding open innovation investigates the importance of internal mechanisms to integrate externally-sourced knowledge and technology, such as absorptive capacity and internal R&D input (Bogers and Lhuillery, 2010; Cohen and Levinthal, 1989; Ettlie and Reza, 1992). In accordance with the open innovation principle concerning the complementary rather than substituting role of openness (Chesbrough and Crowther, 2006), this new paradigm particularly underscores the internal modes and configurations which are imperative for managing the more external-oriented innovation processes (Christensen et al., 2005; Grönlund et al., 2010). Therefore not only the external focus but also the internal perspective should be highlighted in the open innovation studies.

Based on our reading of the relevant literature, we have constructed the conceptual framework for this study by integrating both internal and external elements, namely the three main streams of underlying theories in the area of open innovation as discussed above.

Hypotheses are the presented based upon this conceptual framework. The external elements focus on the relationship between open approaches and innovation performance, and external knowledge sources and innovation performance respectively. The internal perspective examines the role of in-house research in catalyzing the benefits of openness in terms of input in R&D and investments in absorptive capacity.

Open approaches and innovation performance

It has been suggested that the primary processes adopted by open innovators are collaborative or transactional (Christensen et al., 2005; Igartua et al., 2010). Thus, we

adopt inter-organizational collaborations, technology acquisitions, and R&D contracting-out (outsourcing) arrangements as measures of a firm's open innovation approaches.

Collaborative R&D arrangements have been shown as optimal arrangements to obtain complementary knowledge from partner firms. In addition to enhancing the potential variety and availability of external knowledge, collaborations and alliances also provides the platform for knowledge transfer with a high degree of reciprocity (Belderbos et al., 2004, 2006; Stuart, 2000). The acquisition of external technology can also follow transactional arrangements, for example, the purchase of patents, trademarks or licenses (Sen and Rubenstein, 1989). The increasing importance of technology acquisition to complement firms' internal technology portfolios has been widely acknowledged (Veugelers, 1997; Veugelers and Cassiman, 1999). Another transactional form of technology acquisition is R&D contracting-out — outsourcing the innovation activities from an R&D contractor or consulting agency (Veugelers and Cassiman, 1999). Different from direct technology purchase, this form of environmental engagement is usually adopted to obtain specialist skills that a firm does not necessarily need to retain in-house because of insufficient or lumpy demand (Howells, 1999).

The common advantages of these open innovation approaches can be essentially reflected by the value-creation benefits they can provide that exceed the traditional innovation arrangements occurring within firm boundaries. Examples of these include the potential for the fluid transmission of complementary expertise and resources between firms, the deepening and enrichment of firms' knowledge bases (Hagedoorn and Duysters, 2002; Haour, 1992); the access to external specialized know-how that the firms may lack to overcome existing technological deficiencies (Powell et al., 1996); and the sharing of risks, research costs and rewards among collaborators (Grandori, 1997). Additionally, firms may gain a technological edge or lead time advantage relative to rivals through the realization of temporal synergies or scale and scope economies (Negassi, 2004).

Based on this analysis, we propose the following hypothesis:

H1a: Basic open innovation approaches, such as inter-organizational collaboration, technology acquisition and R&D contracting-out, will positively affect (both product and process) innovation performance.

However, different approaches tend to play different roles in acquiring external knowledge and in turn shaping innovation performance. Compared with other approaches, the outsourcing of R&D activities leads to heightened uncertainties vis-à-vis innovation outcomes.

Given open innovation's focus on the complementarity between internal and external research activities, it has been noted that firms should not outsource their entire R&D function (Chesbrough and Crowther, 2006). It has been suggested that an arrangement whereby firms reserve their key technology developments in-house, while contracting out more peripheral activities to outside R&D suppliers, reduces the unintentional spillover of key knowledge and technology to external agents (Ulset, 1996). According to Sen and Rubenstein (1989), firms should still focus on the strategic technological areas in which internal R&D can provide the most competitive advantage while contracting out less significant areas. These areas are primarily non-specialized, and may include more routine research tasks (Howells, 1999; Veugelers and Cassiman, 1999). Thus, as R&D outsourcing is used more selectively and generally only partially, we would expect that it is likely to have a relatively weaker impact on innovation performance:

H1b: Regarding the three basic approaches to open innovation discussed previously, R&D contracting-out tends to have a relatively weaker impact on innovation performance than the other two.

External knowledge sourcing and innovation performance

Previous studies have recognized the strategic importance of the wide range of knowledge sources for innovation (involving the linkages of customers, suppliers, competitors and research institutions), not only for product innovation success (von Hippel, 1988) but also for process innovation facilitation (Reichstein and Salter, 2006).

While the notion of firms' degrees of openness has been variously defined, it can generally be operationalized in terms of the scope of external sources of knowledge used by the firm (Katila and Ahuja, 2002; Laursen and Salter, 2006). Studies by these researchers have found empirical support for the existence of a curvilinear (inverse U)

relationship between knowledge sourcing and innovation performance.

Such a finding implies that a certain level of openness is necessary to encourage innovation — this being consistent with the basic assumption in the open innovation literature that some vibrancy of relations with users, suppliers and competitors is often beneficial for achieving innovation effectiveness (Laursen and Salter, 2006). However, inefficiencies might develop when excessive search actually begins to inhibit the innovation effectiveness of firms. If the scope of external sources employed (i.e. a firm's search breadth) is too broad, various diseconomies might occur which would be observed when dealing with multiple external partners (Belderbos et al., 2006). Such tendency toward 'over-search' (Katila and Ahuja, 2002) might distract managerial attention from the real priorities in knowledge utilization and commercialization (Laursen and Salter, 2006).

Therefore, if the benefits originating from incorporating more external sources do not outweigh the problems which over-search and over-openness create, a negative marginal impact of external knowledge sourcing will occur, eventually detracting from the initial positive returns gained from openness. On this basis, we hypothesize:

H2: The degree of openness (as defined by the scope of external sources employed) is curvilinearly (taking an inverted U-shape) related to (both product and process) innovation performance.

Internal R&D and innovation performance

It might be assumed that under the open innovation paradigm, firms will forego investments in internal R&D, and their associated costs and risks, while compensating for this loss by drawing on knowledge and expertise from a broad range of external sources. This contention tends to ignore potential synergy-based complementarities that may be generated through the successful integration of internal and external knowledge and technology, which may yield strong results in terms of innovation and innovation appropriation (Arora and Gambardella, 1990; Cassiman and Veugelers, 2006).

Thus in-house R&D need not become obsolete or decline when open innovation strategies are followed — indeed openness may even stimulate internal research investments in search of such synergies (Chesbrough and Crowther, 2006). Further, in addition to the traditional role of generating innovation alone, in-house R&D may act

as a catalyst to facilitate the transformative efficiency and effectiveness once the knowledge reaches the focal firm (Cohen and Levinthal, 1989; Lichtenthaler and Lichtenthaler, 2009).

This argument could be summarized by the main principle of open innovation that “external research may function more as a complement than as a substitute in the performance of internal R&D activities” (Chesbrough and Crowther, 2006: 235). Based on these considerations, we predict that internal R&D input can still benefit firms’ innovation performance in the context of open innovation.

H3a: Internal R&D input will positively affect (both product and process) innovation performance even while firms are pursuing open innovation arrangements.

However, we suggest that the role of internal R&D might differ in different types of innovation. According to Ettlie (2006), in most situations, process innovation tends to be ‘bought in’ from outside rather than developed internally in organizations. Given the innate difficulties in differentiating between product and process related expenditures (Reichstein and Salter, 2006), traditional internal R&D investments tend to focus on the development of new products or services at the expense of new processes. This is supported by Rouvinen’s (2002) empirical study which reported an insignificant relationship between investments in R&D and process innovation. According to Hatch and Mowery (1998), technological process innovation is usually facilitated through learning-by-doing within organizations and is therefore not usually dependent on formal R&D activities.

Hence, process related innovation input is rarely R&D-centric. Thus formal R&D investments flow more to product innovation, and consequently will be more closely related to the product innovation performance. This argument can be stated in the following hypothesis:

H3b: Internal R&D input will have a greater impact on product innovation performance than on process innovation performance.

Absorptive capacity and innovation performance

Apart from internal R&D input, another internal element of the open innovation framework relates to ‘absorptive capacity’. This can be observed through the

existence of a firm's systems and capabilities to affect absorption, integration and exploitation of externally gained knowledge (Cohen and Levinthal, 1989). The potentially positive significance of absorptive capacity in leveraging a firm's knowledge base and facilitating innovation effectiveness has been asserted by much empirical research (e.g. Tsai, 2001; Zahra and Nielsen, 2002). In light of the benefits provided by absorptive capacity, its presence is generally considered an essential requirement for firms pursuing product innovation (West and Gallagher, 2006) and process innovation (Reichstein and Salter, 2006).

Nevertheless, the assertion that investment in absorptive capacity linearly and positively drives innovation performance is moot. First, it is often time-consuming and complex to transform various organizational intangible and tangible assets, and routines, into capabilities embodying absorptive capacity (Zahra and George, 2002). Second, it has been suggested that sometimes external knowledge can only be assimilated when firms manage to change their organizational structure and culture to facilitate open innovation processes, especially when the 'not-invented-here' (NIH) (Katz and Allen, 1982) syndrome is overcome (Laursen and Salter, 2006).

Moreover, the 'path-dependent' nature of absorptive capacity, noted by Cohen and Levinthal (1990), indicates that the effectiveness of absorptive capacity depends on the prior accumulation of knowledge (thus could be seen to drive innovation performance cumulatively). As a result, if a firm has lower levels of absorptive capacity due to the lack of previous investment, this might create further costs for it as it seeks to achieve the given level of absorptive capacity in subsequent periods (Cohen, and Levinthal, 1990). It implies only up to a certain level did absorptive capacity contribute to the higher performance of innovation.

On the basis of this analysis, we hypothesize that there are declining marginal benefits created by absorptive capacity investments with regards to innovation performance:

H4: The investment in absorptive capacity is curvilinearly (taking an inverted U-shape) related to (both product and process) innovation performance in the context of openness.

Methods

Sample

We have utilized data collected by the Australian Bureau of Statistics (ABS) through their 2003 Innovation in Australian Business Survey (IABS) (Australian Bureau of Statistics, 2003). The data provides evidence on innovation-related activities of Australian businesses at the establishment level for the years 2001-2003. Although this dataset is among comparatively the most recent and comprehensive innovation surveys released by the ABS, we have noted that this dataset is now somewhat dated. However, we believe that the validity of our theoretical framework and research design ensures the generalizability of our findings as the issues that we consider are relatively timeless. We expect to get similar findings from more recent datasets in the future.

Furthermore, IABS does provide some advantages over other international surveys, particularly in terms of separating non-technological innovation from technological innovation (Australian Bureau of Statistics, 2003). This is especially suitable for our research as we also differentiated between the technological process innovation and the non-technological organizational process innovation.

The population within which the IABS was gathered included all business units in Australia registered with the Australian Taxation Office and employing more than 4 persons, with the exception of government enterprises or businesses in several specific industries (i.e. Agriculture, Forestry and Fishing; Education; Health and Community Services; Personal and Other Services). The final sample of establishment-level data released by the ABS had 4,520 businesses (Australian Bureau of Statistics, 2003). The sample for our study was refined to ensure comparability and completeness of data provided by these responding businesses. Through a process of careful screening, a sub-sample of 4,322 Australian businesses (including both innovators and non-innovators) was identified for this research. All firms selected provided data for all items of the survey (i.e. there were no missing values included), and had non-zero total expenditures during the period of survey.

Measures

Dependent variables

For this study, we employ three dependent variables (DVs) for our three logistic regression-based models. The first DV 1 (*Innovtr1*) is akin to a measure of innovation performance often utilized in the innovation literature — namely the dichotomous response to the question of whether a firm had released a new product or service in

the period under investigation. The second DV 2 (*Innovtr2*) marks the response to the question regarding whether the firm had introduced a new operational process internally (this has been indicated earlier as the primary form of technological process innovation). The final DV 3 (*Innovtr3*) measures the deployment of new organizational/managerial processes.

Each business was asked whether it had introduced or implemented any of these forms of innovation during the calendar year 2003. The original responses were coded by IABS into dichotomous variables with a value of zero (0) if no such innovation had occurred, and one (1) if it had. Actually DV 2 and DV3 are both encompassed in the main innovation type – process innovation. They are treated as separate processes for modelling here given the distinctive innovative features between them.

Independent variables

Open Approaches — The three basic approaches to open innovation, namely inter-organizational collaborations, technology acquisition and R&D contracting-out (the definitions and scopes of these concepts have been addressed earlier in this paper) are adopted as the measures of basic open innovation approaches. However, we do realize that these measures only capture the inbound stage of open innovation (Chesbrough and Crowther, 2006). A more complete range of measures encompassing both inbound and outbound open innovation approaches should be considered in future studies when the data permits.

The use of Inter-organizational Collaborations (*Collaboration*) is measured by aggregating the six survey questions relating to whether the business had engaged in any collaborations with other businesses in the form of joint marketing or distribution, joint manufacturing, joint research and development, other joint ventures, licensing agreements, or other forms of collaboration. Each question is a binary variable taking the value of 1 when the business indicates that it had used this type of collaboration and 0 otherwise. Therefore, the aggregate ordinal measure ranges from 0 to 6. This measure is in line with the findings of Bogers and Lhuillery's (2010) study that while the incorporation of external knowledge is most often associated with R&D, other organizational functions like manufacturing and marketing have also been shown to be amenable to such integration.

Technology Acquisition (*TechAcquisition*) is constructed in terms of the technology buy-in intensity that is calculated by dividing a firm's total expenditures

on all activities by its accumulated expenditure on machinery, equipment, licenses, patents and other intellectual property acquired to develop innovations.

R&D Contracting-out (*Outsourcing*) is measured by the responses to the question relating to whether the business had contracted out research and development to higher education or research institutions, based either in Australia or overseas. The original responses had been aggregated by the ABS into a dummy variable with the value of one (1) if the business contracted out R&D to these institutions and zero (0) otherwise.

The Degree of Openness (*Sources*) — has been defined as the scope of external sources of knowledge or information used by the business. As indicated earlier, it is partially adapted from Laursen and Salter's (2006) study that tested the impact of the use of a wide range of innovation sources. The IABS listed 11 key external sources of knowledge which help the business to develop new goods/services, new operational and organizational processes, comprising three main categories — market sources (clients, suppliers, consultants and competitors), institutional sources (universities, government agencies, private research institutions, and commercial laboratories) and other sources (professional conferences etc., websites and journals, and others). Each business was asked to indicate the sources it had used. By aggregating their responses, this variable builds on an ordinal scale of measurement, taking the value of 0 when no external sources were used and 11 when all these potential sources had been used. Therefore, it is assumed that businesses with the higher values of this variable (i.e. the higher number of using external sources) are relatively more 'open' than others.

R&D Input (*R&DInput*) — has been calculated based on the proportion of the estimated expenditure on research & development activities of new or changed goods (services) or processes to the total expenditures of the focal business. However, there is a limitation in this measure in that the survey questions did not make adequate distinction between process and product R&D expenditures.

Investment in Absorptive Capacity (*ACAP*) — In this study we use a proxy measure for absorptive capacity, namely the human capital of the whole organization. This serves two purposes. On one hand this measure can effectively overcome the biases caused by the traditional measure of R&D intensity which does not consider the quality of R&D work undertaken within the firm (Schmidt, 2009). On the other hand it also takes into account the knowledge absorption and exploration in the process innovation forms which might involve the whole organization to embody the

required absorptive capacity rather than centrally rely on R&D (Arbussa and Coenders, 2007). This measure is supported by the argument of Hitt et al. (2001) and Vinding (2006), and is also consistent with some empirical studies that paid attention to this measurement issue (Becker and Peters, 2000; Luo, 1997).

This variable is built cumulatively by combining three main survey questions with every question constructed by a binary variable with 1 for yes, and 0 for no — whether the business had employed new skilled staff (either from within 100km, or from elsewhere in same state of territory, or from elsewhere in Australia, or from overseas); whether the business had employed new graduates (either from Australian higher education or research institutions or from overseas institutions); and whether it had employed academic or research staff (either from Australian higher education or research institutions or from overseas institutions).

Control variables

In addition to these independent measures, we control for the effects of firm size and industry for each business. Firm size (*Size*) is measured by the number of persons working for the business. The responses to this question were released as a categorical variable on a 1-2-3 scale (1 for 5-19 persons, 2 for 20-99 persons, 3 for 100 or more persons). We also include an industry dummy (*Industry*) with the value of 1 if the business was in the manufacturing industry and 0 otherwise to compensate for the different overall levels of innovation and propensities towards openness between manufacturing and non-manufacturing firms.

Results

Binary logistic regression was employed as all DVs are dichotomous variables coded 0 or 1 respectively (and thus do not meet the assumptions of OLS regression). Additionally, we adopted the hierarchical form in this study with only control variables and the linear term of independent variables included in the basic model, then the squared terms $Sources^2$ and $ACAP^2$ were entered step by step to examine their inverted U-shape effects according to our Hypothesis 2 and Hypothesis 4.

The overall descriptive statistics for variables and correlations among them are presented in Table 1. The possibility of multicollinearity was considered for this

study, though rejected as all of the Variance Inflation Factors (VIFs) are less than 1.5 (the maximum VIF is 1.381, and the average is 1.136), thus within the generally acceptable level of less than 5 (Studenmund, 2006) and also below the general threshold 2.5 for logistic regression models (Allison, 1999).

Table 1. Means, standard deviations and correlations.

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10
1. <i>Innovtr1</i>	0.203	0.402										
2. <i>Innovtr2</i>	0.250	0.433	.46**									
3. <i>Innovtr3</i>	0.241	0.428	.36**	.48**								
4. <i>Collaboration</i>	0.335	0.925	.33**	.30**	.35**							
5. <i>TechAcquisition</i>	0.009	0.048	.25**	.15**	.11**	.11**						
6. <i>Outsourcing</i>	0.019	0.137	.11**	.12**	.09**	.17**	.05**					
7. <i>R&DInput</i>	0.012	0.069	.10**	.06**	.03*	.09**	.08**	.01				
8. <i>Sources</i>	2.384	2.096	.29**	.31**	.32**	.28**	.09**	.20**	.07**			
9. <i>ACAP</i>	0.494	0.927	.27**	.30**	.32**	.26**	.09**	.24**	.09**	.40**		
10. <i>Size</i>	1.739	0.793	.18**	.24**	.20**	.14**	-.01	.14**	-.03*	.18**	.35**	
11. <i>Industry</i>	0.423	0.494	.10**	.02	-.02	.01	.05**	.03*	.03*	-.02	-.07**	-.08**

n=4322

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

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

The results regarding logistic regression analysis for three dependent variables are demonstrated in Tables 2 – 4 respectively. Of our control variables, the size of the firm (*Size*) seems to positively ($p < .001$) influence innovation performance for each of our three types of innovation. It seems within our sample that manufacturing firms are more likely to introduce new products/services and operational process than service firms ($p < .001$ and $p < .01$ for product innovation and operational process innovation respectively), although this dummy variable is not significantly associated with the introduction of new organisational /managerial innovation ($p > .10$).

All three models provide acceptable fit for the respective dependent variables indicated by the values of Nagelkerke R^2 (around 25% to 32%). Within all three models, both *inter-organizational collaboration* and *technology acquisition* co-vary positively and significantly ($p < .001$) with innovation performance (as measured by the introduction of new products/services, new operational processes and new organizational/managerial processes), while *R&D contracting-out* is reported insignificant ($p > .10$) for product/service and operational process innovation and

slightly significant for new organizational/managerial process. We thus note that our first hypothesis H1a is partially supported while our H1b is supported within each of the three types of innovation discussed.

Our second hypothesis proposing a curvilinear (inverted U-shape) relationship between the *degree of openness* (in terms of the scope of external sources employed) and innovation performance finds support for each of the three types of innovation. It is because (1) the coefficient of the independent variable *Sources* is positive and highly significant ($p < .001$ for all types of innovation), showing that the degree of openness is important in determining innovation performance (as measured by the introduction of new products/services, new operational processes or new organizational/managerial processes) (2) the *Sources*² is negative and highly significant as well ($p < .001$ for all), indicating a declining marginal effect of the extent of openness. There is also an improvement of explanatory power of the model (indicated by Nagelkerke R^2) with the introduction of the squared term.

Our third hypothesis investigating the role of internal R&D in the context of openness is also just partially supported because the findings suggest that the inputs in R&D only affect the product/service innovation performance positively and significantly ($p < .01$), but neither for the introduction of new operational nor organisational/managerial processes ($p > .10$ for both). However, in this sense, its weaker impact on process innovation performance than on product innovation performance proposed by H3b is supported.

The same principle for results regarding H2 can be used to explain the fourth hypothesis which is observed as partially supported as well, as the inverse curvilinear relationship between investments in absorptive capacity and innovation performance is found relating to the introduction of new operational, organisational/managerial processes although not for the first type of innovation (i.e. the introduction of new products/services). This is illustrated statistically due to the fact that *ACAP* has a positive and significant coefficient ($p < .001$ for both type of process innovation), while the *ACAP*² has a negative and significant coefficient ($p < .001$ for both), and there is also an improvement in the model fit (indicated by Nagelkerke R^2) when the square term is introduced.

Table 2. Results of logistic regression analysis for innovation performance.

(New products/services)

Independent Variables ↓	Dependent Variable: Innovation Performance		
	(New Products/Services)		
(Constant)	-3.484***	-3.903***	-3.909***
Firm Size (<i>Size</i>)	0.365***	0.367***	0.365***
(Manufacturing) Industry Dummy (<i>Industry</i>)	0.645***	0.641***	0.644***
Inter-organizational Collaboration (<i>Collaboration</i>)	0.490***	0.497***	0.493***
Technology Acquisition (<i>TechAcquisition</i>)	17.725***	17.308***	17.283***
R&D Contracting-out (<i>Outsourcing</i>)	-0.376	-0.214	-0.188
Degree of Openness (<i>Sources</i>)	0.210***	0.575***	0.564***
R&D Input (<i>R&DInput</i>)	1.426**	1.397**	1.388**
Absorptive Capacity (<i>ACAP</i>)	0.274***	0.292***	0.402**
Degree of Openness Squared (<i>Sources</i> ²)		-0.052***	-0.051***
Absorptive Capacity Squared (<i>ACAP</i> ²)			-0.031
Chi-square	925.647 ***	967.110***	968.609 ***
-2 Log likelihood	3429.059	3387.596	3386.097
Nagelkerke R Square	30.4 %	31.6%	31.6%

n=4322

† p < .10

* p < .05

** p < .01

*** p < .001

Table 3. Results of logistic regression analysis for innovation performance.

(New operational processes)

Independent Variables ↓	Dependent Variable: Innovation Performance		
	(New Operational Processes)		
(Constant)	-3.096***	-3.462***	-3.501***
Firm Size (<i>Size</i>)	0.486***	0.491***	0.488***
(Manufacturing) Industry Dummy (<i>Industry</i>)	0.250**	0.242**	0.251**
Inter-organizational Collaboration (<i>Collaboration</i>)	0.431***	0.436***	0.423***
Technology Acquisition (<i>TechAcquisition</i>)	5.196***	5.148***	5.205***

R&D Contracting-out (<i>Outsourcing</i>)	-0.108	0.041	0.141
Degree of Openness (<i>Sources</i>)	0.224***	0.563***	0.521***
R&D Input (<i>R&DInput</i>)	0.571	0.526	0.505
Absorptive Capacity (<i>ACAP</i>)	0.278***	0.292***	0.730**
Degree of Openness Squared (<i>Sources</i> ²)		-0.050***	-0.045***
Absorptive Capacity Squared (<i>ACAP</i> ²)			-0.127***
Chi-square	814.833***	859.344***	889.195 ***
-2 Log likelihood	4044.893	4000.382	3970.532
Nagelkerke R Square	25.4%	26.7%	27.5%

n=4322

† p < .10

* p < .05

** p < .01

*** p < .001

**Table 4. Results of logistic regression analysis for innovation performance.
(New organizational/managerial processes)**

Independent Variables ↓	Dependent Variable: Innovation Performance (New Organizational/Managerial Processes)		
(Constant)	-2.763***	-3.036***	-3.080***
Firm Size (<i>Size</i>)	0.303***	0.306***	0.301***
(Manufacturing) Industry Dummy (<i>Industry</i>)	-0.013	-0.019	-0.010
Inter-organizational Collaboration (<i>Collaboration</i>)	0.613***	0.613***	0.600***
Technology Acquisition (<i>TechAcquisition</i>)	3.100***	3.035***	3.075***
R&D Contracting-out (<i>Outsourcing</i>)	-0.697*	-0.552*	-0.425
Degree of Openness (<i>Sources</i>)	0.220***	0.480***	0.432***
R&D Input (<i>R&DInput</i>)	-1.011	-1.099	-1.066
Absorptive Capacity (<i>ACAP</i>)	0.377***	0.384***	0.875***
Degree of Openness Squared (<i>Sources</i> ²)		-0.039***	-0.033***
Absorptive Capacity Squared (<i>ACAP</i> ²)			-0.142***
Chi-square	855.629***	880.562***	917.209***
-2 Log likelihood	3918.759	3893.826	3857.179
Nagelkerke R Square	26.9%	27.6%	28.6%

n=4322

† p < .10

* p < .05

** p < .01

*** p < .001

Discussion & Conclusion

In spite of the recent emergence of much empirical research in the open innovation arena, analysis relating to the impacts of openness on process innovation has hitherto been under-explored. This study seeks to address this gap through an empirical examination of a large sample of Australian firms. Table 5 illustrates a summary of analytical findings relating to the four hypotheses for each type of innovation in our sample.

Table 5. Results of hypotheses testing.

Hypotheses Testing	Dependent Variables		
	New Products/ Services	New Operational Processes	New Managerial Processes
H1a: Basic open innovation approaches will positively affect (both product and process) innovation performance.	Partially Supported	Partially Supported	Partially Supported
H1b: R&D contracting-out tends to have a relatively weaker impact on innovation performance than the other two.	Supported	Supported	Supported
H2: The degree of openness is curvilinearly (taking an inverted U-shape) related to (both product and process) innovation performance.	Supported	Supported	Supported
H3a: Internal R&D input will positively affect innovation performance even while firms are pursuing open innovation arrangements.	Supported	Not Supported	Not Supported
H3b: Internal R&D input will have a greater impact on product innovation performance than on process innovation performance.	Supported		
H4: The investment in absorptive capacity is curvilinearly (taking an inverted U-shape) related to (both product and process) innovation performance in the context of openness.	Not Supported	Supported	Supported

There are a number of interesting findings from our empirical results. First, two basic external approaches — namely inter-organizational collaborations and technology acquisition — have similarly significant effects for each of the two main types of innovation, namely product and process innovation (operational and organizational/managerial innovation can be generally termed process innovation). The declining marginal effect of external knowledge sourcing also finds support for each of the main types of innovation.

Despite the similar effects of external open innovation strategies discussed above, the internal inputs, namely the R&D expenditure (a form of the internal formal

commitment of innovation resources) and the investment in absorptive capacity affect performance of product innovation and process innovation in different ways.

Internal research enhances innovation performance for firms only in their introduction of new goods/services and we do not find support that such expenditure of in-house R&D anticipated the introduction of new operational or organizational/managerial processes. It implies that when external research and external knowledge is used for the adoption of open innovation strategy, internal R&D becomes less important in introducing new processes within the organization. This, as we predicted earlier, may largely be due to the fact that the investment in formal R&D is generally viewed as expenditure explicitly aimed at the production of traditional product or service innovation, while expenditure on improvements in the way an organisation functions is seen not so much as R&D, but rather as 'business as usual' expenditure.

It is observed that there is a curvilinear relationship between investments in absorptive capacity and innovation performance relating to the introduction of new processes (both operational and managerial/organizational), although not for the introduction of new products/services. This indicates that the continued increase in the employment of such personnel may, after a time, tend to diminish performance of process innovation within the firm. A possible explanation for the stronger diminishing marginal effects on process innovation than on product innovation might still be related to the cost-benefit relationship involved in the development of absorptive capacity.

It is suggested that although the value of process innovation would be also realized through commercialization (Ettlie and Reza, 1992), there are less commercialization opportunities for new processes than new products and/or services, since product innovation is mainly triggered by the market with the external focus while process innovation is efficiency driven with an internal focus (Utterback and Abernathy, 1975). For customers, the benefits of process innovation may be two steps removed from the products and services that they purchase, in particular for organizational process innovation. According to Edquist et al (2001), original organizational process innovation is seldom sold and bought on the market. Such discussion is also compatible with Damanpour and Gopalakrishnan's (2001) point of view that new processes are intermediately related to the production and the delivery of more tangible innovation outcomes, and thus generate relatively less revenues than

successful products. As newly introduced processes are generally not directly commercialized to the market, the financial returns brought by building their absorptive capacity may not be immediately obtained to justify the investment in this capacity. Consequently, the cost-benefit ratio for process innovation (which exceeds the ratio for product innovation) leads to a non-linear, positive but marginally declining impact of absorptive capacity.

Based on the discussion above, we find that, given the nature and inherent characteristics of process innovation, process innovation faces more challenges in realizing the benefits of open innovation strategies than is the case for product and service innovation. These characteristics include process innovation's limited reliance on internal R&D and few commercialization opportunities. These characteristics, to some extent, result in the declining effect of in-house research investments and the adverse impact of over-investment in absorptive capacity for process innovation.

Therefore, we suggest that, when managers adopt open innovation strategies to introduce new processes in their organizations, they should pay attention not only to the external knowledge sourcing and technology acquisition, but also to the utilization of internal resources and capabilities. They particularly need to make sure an appropriate level of investment in the internal R&D and absorptive capacity building is achieved.

By doing this, the benefits resulting from openness tend to outweigh its potential costs and uncertainties and firms are more likely to take advantage of open innovation strategies to facilitate their process innovations as well as product innovations.

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