Openness and Appropriation: Empirical Evidence from Australian Businesses

Abstract: The adoption of open innovation creates a dilemma for firms. On the one hand, a commitment to openness facilitates the flow of knowledge between firms, with this flow (generally) unconstrained by royalties and other appropriation mechanisms. However, openness has also led to unintended knowledge spillovers, limiting firms' abilities to protect their core knowledge. This dilemma has created a need to consider the relationship between openness and firms' appropriability regimes. In order to explore this 'paradox of openness', an investigation of the appropriability regimes adopted by Australian firms through an empirical analysis of innovation-related data from 4,322 businesses was undertaken. It was found that the relationship between two indicators of openness (the breadth of external knowledge sources and the scope of inter-organizational collaborations) and the scope of appropriability regimes employed by a firm exhibits a non-linear, inverse-U (∩) form. The results also indicated that open innovators actually increase controls on their intellectual property through informal appropriability regimes rather than loosening appropriability mechanisms to promote knowledge spillovers as open innovation theories suggest.

Keywords: open innovation, appropriation, paradox of openness, Australian businesses

Managerial Relevance Statement: This research has provided practitioners with insights regarding how to appropriate returns from tangible and intangible knowledge assets while implementing open innovation. In order to benefit from openness, firms need to gradually reduce the control on their intellectual property, particularly in terms of their use of informal appropriability regimes, to promote effective knowledge exchanges. However, managers must balance knowledge sharing and knowledge protection. This balance can be maintained by continually evaluating knowledge flows, both inward and outward, by monitoring and adjusting the appropriability regime portfolio and by carefully developing relationships with external partners to ensure a balanced 'give and take' relationship.

1. Introduction

At a time of increasingly complex technologies, higher level of uncertainty surrounding research and development (R&D), increasingly costly R&D projects and shorter innovation cycles, developing innovations entirely 'in-house' is increasingly seen as sub-optimal [1],[2]. The theoretical and empirical moves towards an externally-oriented view of innovation are best encapsulated in the 'open innovation' literature [1],[3]. Open innovation entails "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" [3, p.1]. Strategies based on open innovation have been increasingly viewed as a potential source of competitive advantage in terms of their capacity to enable innovation, to generate opportunities to profitably leverage 'on the shelf' intellectual capital, to drive organizational growth and to improve the long-term competitive position of firms across industries [1],[4],[5].

This research sought to shed some light on an unresolved paradox in the theoretical assumptions relating to inbound open innovation, namely the relationship between the access to external knowledge through inbound mechanisms and the use of appropriability regimes[1] of open innovators. Open innovation suggests that the generation of innovative outputs is facilitated by enhanced fluidity of knowledge and information flows between firms [1]. Such flows are enhanced

[1] Henceforth in this paper the term 'appropriability regimes' is used to refer collectively to those formal and informal arrangements that firms may use to extract returns from their intellectual and tangible resources. This follows the development and use of this term by [6], [7] and others.

when they are generally unconstrained by excessive appropriation of knowledge royalties [8],[9]. Shared appropriability regimes have also been recognized as a means of encouraging sharing of various forms of knowledge and their concomitant rents [9]. A common conclusion of these works is that shared benefits are maximized through the reduction of transactional costs and the minimization of appropriability constraints between firms [10],[11].

However, these assumptions imply a paradox of openness with regard to the appropriability regimes affected by open innovation practices [8]. On the one hand, open innovation encourages firms to reduce the appropriability constraints, and disseminate knowledge to increase their use by others rather than leave them in house [1]. Firms are likely to gain numerous benefits from their innovations in this way [12]. On the other hand, in the context of openness, the necessity to disclose knowledge leads to unintended and involuntary knowledge spillovers, requiring firms to control potential intellectual property (IP) rights. In that sense, there might be a creative tension between the knowledge disclosure and spillover effects resulted from openness, and the protections and returns facilitated by appropriability regimes. This might be in essence a reflection of the tension between cooperation and competition [13].

This paradox requires a consideration of the complex impacts of inbound open innovation arrangements upon the appropriability regimes employed by firms. As suggested by Laursen and Salter [14] and West [8], most extant research that does address open innovation fails to articulate the ambiguous theoretical underpinnings regarding the appropriation approaches taken by ‘open innovators’. Therefore, this paper sought to address this largely neglected area in the open

innovation literature: how does openness actually affect a firm's management of appropriability regimes to garner benefits from its innovations? This study attempted to address this research question by quantitatively examining inbound open innovation in terms of external knowledge sources and knowledge access channels, and their effects on the decisions regarding the use of appropriation regimes in terms of both formal and informal IP protection instruments.

2. Literature Review

2.1. Defining Open Innovators

Chesbrough's definition essentially implies that there are two dimensions of open innovation activities — *inbound* open innovation and *outbound* open innovation [4]. In respect to the new product development event, inbound open innovation refers to the *ex-ante* processes of actively in-sourcing and absorbing knowledge from external environment to supplement a firm's internal R&D, while outbound open innovation represents the *ex-post* and purposeful search activities to facilitate external commercialization paths for creative ideas generated in house [1],[16].

Although the term 'open innovation' is relatively recent, it does not represent a new organizational phenomenon [16],[17]. Theories that can be seen as antecedents to our modern understanding of inbound open innovation highlight two main themes — external sources from which the exogenous knowledge emerges, including from customers, suppliers, competitors, government agencies and research institutes [18],[19]; and channels through which knowledge can be inwardly transferred, such as technology in-licensing, inter-firm collaboration and joint development [16],[17].

The first stream relates to the inward knowledge flows to firms [1],[3] in that some "innovative firms now spend little on R&D and yet they are able to successfully innovate by drawing in knowledge and expertise from a wide range of external sources" [19, p.132]. Empirically consistent with much of the 'sources of innovation' literature (e.g. [22],[23]), to access these sources, Chesbrough [1] specifically suggests that the boundaries of firms must become more porous, facilitating the formation of various ties across their boundaries [24]. These ties involve linkages with a wide range of crucial parties such as consumers, lead users, suppliers, universities, research centres and other actors to establish value networks for firms in the context of open innovation [25],[26].

The use of external knowledge sources helps firms to identify potentially valuable opportunities for innovation during the early stages of technology development, while also shaping the roles of partners in creating and capturing value at the final stage of commercializing innovation outputs [27],[28]. The scope of external sources of knowledge is the most commonly used measure of the degree of openness for firms. Lazzarotti and Manzini [10] operationalized this notion as 'partner variety' in their research, i.e. a typology of the variety of partners with which a firm collaborates. Laursen and Salter's [19] study also assessed the number of external sources of innovation. They defined this measure as 'external search breadth', ensuring its inclusion in later studies as a key measure of openness. The findings of these studies imply that those firms utilizing a larger number of external sources of knowledge tend to be relatively more 'open' than others.

The second body of literature examined here relates to the various means by which firms access and acquire external knowledge. These means include the purchase and acquisition of knowledge and technology through the marketplace or through active and deliberate cooperation with other firms [12],[29],[30]. Common among these studies is the jointly transactional and collaborative nature of open innovation [17],[31].

Accordingly, the two measures ‘technology purchase’ and ‘inter-organizational collaboration’ were utilized within the models of this study. Technology purchase is typically seen as a form of transactional arrangement undertaken to acquire external knowledge and technology, including through the purchase of patents, trademarks or licenses [32],[33]. Such arrangements facilitate the ‘buy’ option for firms facing ‘make or buy’ decisions (relating to the alternative options of conducting in-house R&D or commercially buying in technology) [1],[34].

Moreover, firms often depend on a variety of informal inter-organizational collaborations to minimize transaction costs and opportunism [15]. These arrangements are intended to be less formal than the transactional technology purchases, and are regarded as an essential means by which inbound open innovation functions in gaining access to complementary knowledge and quickly responding to changing market conditions and strategic opportunities [35],[36],[24].

Therefore ‘open innovators’ can be defined based on these two themes of inbound open innovation — namely firms that are involved with a broader *scope of external sources of knowledge* and engaged in more various *inter-organizational collaborations* and *technology purchase activities* to obtain knowledge from outside are comparatively more ‘open’ than others.

These three constructs will also be employed as the main variables jointly measuring the ‘degree of openness’ for the focal firms in the models of this study. That is to say, firms with a higher degree of openness can be relatively considered open innovators.

2.2. Inbound Open Innovation and Appropriability Regimes

Certain attributes of industrial knowledge, including its intangible nature and its cumulativeness and indivisibility, make knowledge diffusion and management a highly challenging task [37]. The principal tasks of knowledge management are often presented as exploration, exploitation and retention [38],[39],[40]. In the context of inbound open innovation, firms mainly involve themselves in different exploration activities across their boundaries to overcome knowledge deficiencies and assist them in accelerating their innovation efforts [1],[3],[19],[41]. To engage more effectively in external knowledge networks, the exploration process often entails firms making some knowledge and resources available to other firms. This might create some managerial tensions. By necessity effective knowledge exploration includes the protection of an organization’s core knowledge because a firm’s competitive advantage lies in its “ability to create, transfer, assemble, integrate and exploit knowledge assets” [37, p.75] through various appropriability regimes.

There are numerous IP protection instruments that facilitate the appropriation of firms’ intellectual assets [43]. These are generally divided into two groups — formal mechanisms that legally preclude the non-agreed use of knowledge by competitors (such as patents, copyrights, trademarks and other forms of protection including registered design), and informal methods that

protect technology from unanticipated outflows (such as lead time, firm secrecy and complexity of design) [44],[21]. Some empirical research has looked at the use of patenting, copyright and trade secrecy by open innovators [21],[8], however, this has not been a significant area of research focus thus far.

This study sought to thoroughly assess how openness impacts the scope of appropriability regimes that open innovators follow. Firms' openness with respect to external parties is likely to require some form of IP protection. This may take on a variety of forms including relying upon informal approaches such as trade secrets through to formal approaches such as patents and copyrights. The appropriate choice of IP protection can be a function of the technology, industry and internal resources [45],[46].

3. Hypotheses Development

3.1. The Degree of Openness and the Use of IP Appropriability Regimes

Traditionally, the choice of IP appropriability regimes has been contingent upon firm-level factors (such as size) as well as nature of the external partners with which the firm engages [46],[47],[43]. Firms may engage through the use of vertical linkages with suppliers and buyers, horizontal interaction with partners and competitors, or networking with universities and research institutes [48],[49]. As previously discussed, the focal firm's degree of openness towards its external environment was operationalized in this study by assessing both the breadth of external knowledge sources employed, and the scope of collaborative and transactional partners involved through inter-organizational collaborations and technology transactions).

Firms may, on an ad-hoc basis, set different requirements regarding the degree of knowledge disclosure to these various sources and partners. In a study within mobile telephony handset manufacturing, Galvin and Rice [50] found that firms differentiate their sharing strategies between partners, and between knowledge types, on a contingent basis. As such, the differentiated knowledge disclosure and sharing effect is largely determined by the different protection mechanisms that firms adopt.

Firms may utilize formal IP controls to safeguard themselves from their competitors' opportunism [51]. On the other hand, patents and other formal instruments could be also used as a means to purposely reveal important information to partners in order to jointly drive investment, market growth, or promote lead-user adoption [52]. For example, firms cooperating with universities tend to use patenting more frequently as an IP appropriability regime [43]. Firms may also utilize informal instruments such as secrecy, speed to market, limits on employee mobility or other arrangements [21],[53]. For instance, firms with "horizontal collaborative innovation arrangements are statistically significantly more likely ... to emphasize speed [to market]" [43, p.1478]. In summary, the variety and selection of appropriation arrangements adopted by firms has been shown to be highly contingent, often strategic, and made in reference to a variety of internal, market, and relationship-specific factors.

As a result, firms with a higher degree of openness tend to employ a larger scope of appropriability regimes as such they are likely to seek protection for a wider array of knowledge flows between themselves and the various external sources and partners that they contact with. For

example, if (as suggested by the above authors) working with universities tends to see one form of IP appropriability regime employed, while working with competitors tends to see the use of an alternative appropriability regime etc., then the wider the breadth of its search activities, the more IP appropriability regimes a firm is likely to use [54],[55].

However, there are limits to the scope of appropriability regimes used, especially by firms that are highly open. While firms that are more open may use an increasing range of appropriability regimes, there comes a point where a declining marginal utility will emerge on the basis of the complexity and cost. As mentioned earlier, complementary and synergistic effects do exist, but these are subject to a moderate level of the complexity and scope of IP protection portfolio. Therefore, it is proposed that the effectiveness of an increasingly comprehensive IP package might decline as firms become more open.

This effect is partially attributable to the substitutive relationship between and among some appropriability regimes. While the roles of appropriability regimes are generally complementary, the use of a wide range of different methods might inevitably result in some substitutive effect between each other, such as the alternative choices between patents, trademarks or copyrights [56]. Moreover, inefficiencies might arise in terms of the difficulties in the coordination and control of the multiple intellectual assets. Maintaining a wide array of appropriability regimes is expensive and time consuming to put in place. Copyrights, trademarks and patents can all be expensive to register and enforce where necessary [57],[51]. Keeping trade secrets is also costly [58]. In the same way that firms need to place limits on their search activities due to inefficiencies associated

with maintaining numerous sources [19], there are likely to be natural limits to the span of the appropriation regimes put in place.

In order to minimize the collective risks and costs of too many appropriability regime arrangements, firms attempt to optimize these relative to their product portfolio and innovation situation [54]. Firms that are using a variety of appropriation regimes regularly will thus tend to invest in certain appropriability regimes over others to enhance their efficiency. For example, patenting is often viewed as an inferior IP protection mechanism for small firms or firms that patent infrequently due to the costs of establishing, monitoring and potentially enforcing the patent given the need to either internally develop the capabilities to navigate the complex rules and regulations or utilize expensive specialist legal firms [59]. Firms that do make these investments in patenting management, via the employment of patent attorneys and associated support staff, for example, may well integrate patenting into their R&D process [45] to the point that patenting becomes something of a default option for some firms. In much the same way, there are capabilities associated with ensuring an IP protection strategy based on (informal) secrecy actually works. There are clear administrative requirements in respect of law such as “explicitly defining the trade secret and ... providing unambiguous and appropriate notice to employees, visitors and research partners, etc” [46, p.16]. Again, once a firm develops these capabilities, secrecy becomes a more viable IP option in respect of cost and efficiency in managing intellectual assets and thus firms may substitute secrecy over other IP protection mechanisms that might otherwise be seen as optimal.

In summary, it becomes inevitable that highly open firms use some IP appropriability regimes more often than others. This might be due to the counter-balancing effects that exist between some protection instruments. Moreover, the costs and difficulty in managing and coordinating a comprehensive portfolio of appropriability regimes also forces them to only focus upon a more limited set of most effective choices.

Overall, in the first hypothesis it was proposed that firms tend to use appropriability regimes that account for the nature of the partner and the IP in question, therefore those firms with higher levels of openness, would utilize a greater range of appropriability regimes. It was then anticipated that the growth in the variety of appropriation strategies would tend to tail off, and potentially decline at some point of openness. This decline would be due to firms minimizing the collective risks and inefficiencies associated with managing multiple appropriability regimes by investing significantly in a limited set of options.

Hypothesis 1. *The degree of openness (operationalized by the breadth of external knowledge sources employed and the scope of collaborative and transactional partners involved) is curvilinearly (taking an inverted U-shape) related to the scope of IP appropriability regimes.*

3.2. The Adoption of Formal and Informal IP Protection Arrangements by Open Innovators

The discussion in the introductory section illustrated a paradox that open innovators might face: on the one hand, openness facilitates the flow of knowledge between firms, preferably on a relatively fluid basis unconstrained by royalties and other appropriation mechanisms. On the other

hand, openness may lead to unintended and involuntary knowledge spillovers or leakages, requiring firms to exert more control over the knowledge transfer processes and their own IP rights. This paradox can be further explored through this hypothesis.

As discussed earlier, IP appropriability regimes can be categorised into two main types — formal and informal, and they tend to affect knowledge spillovers in differing ways [21]. Various choices made by managers regarding the adoption of IP protection arrangements and appropriability regimes are contingent on a variety of factors, among which an important driver may be the intended extent of knowledge exposure by firms.

While the use of formal protection instruments such as patents, licenses and copyrights is often seen as highly restrictive, these arrangements may actually be seen as active forms of the disclosure of proprietary knowledge to other parties [57],[21],[46]. Such disclosure of protected knowledge represents a kind of voluntary knowledge spillovers, with the aim of transferring complementary knowledge with external parties, including potential competitors [9]. These formal protection methods are used for the purpose of knowledge brokering and knowledge sharing rather than only knowledge protection [1],[12]. The disclosure effect of formal IP protection mechanisms tends to counterbalance, and can even outweigh, their constrictive effects [21]. Therefore, in the open innovation context the effective use of formal appropriability regimes might be seen as a proactive and positive measure to encourage the knowledge disclosure between open innovators [1].

Informal knowledge protection (for example, secrecy) may at first appear to be a less restrictive form of IP protection. On the contrary, such arrangements have the direct, specific and intended

effect of limiting knowledge flows between firms [46]. While the formal appropriation instruments, discussed above, have counterbalancing impacts, informal methods do not have any knowledge disclosure element [46], and hence would largely limit knowledge exchange and knowledge sharing [21].

Firms tending to utilize secrecy and other forms of informal IP protection may be seeking strategic outcomes within their market based upon first mover positioning [21] or differentiation of their products in such a way that replication by competitors is challenging [42]. On that basis, the use of informal protection methods may indeed indicate a genuine aversion of any networking and knowledge spillovers emphasized by open innovation assumptions [54]. Hence this second hypothesis can be proposed as:

Hypothesis 2. *The degree of openness is positively related to the use of formal IP appropriability regimes, and negatively related to the use of informal IP appropriability regimes.*

4. Methods

4.1. Sample

The data for analysis was drawn from the *2003 Innovation in Australian Business Survey (IABS)* provided by the Australian Bureau of Statistics (ABS). This database was chosen because it provided comprehensive details of firm-level innovation activities that were not available from other surveys in the Australian context. Furthermore, the survey questions and frameworks were largely consistent with the Oslo Manual on Innovation [60], therefore maintaining partial

comparability with several international surveys such as the Eurostat Community Innovation Survey (CIS). This facilitates the potential for the comparison between different innovation contexts in future research. The scope of the IABS was all business units in Australia which had registered with the Australian Taxation Office with more than 4 employees in the calendar year 2003, with the exception of government enterprises as well as businesses in several specific industries (e.g. agriculture, forestry and fishing; education; health and community services; personal and other services). The survey was conducted based on a random sampling of businesses within this survey scope. The sample released in the 2003 IABS Expanded CURF included 4,520 respondent businesses, approximately 73% of the businesses that contributed to the survey [61].

This sample was further refined to ensure comparability and completeness of the responses. 4,322 Australian businesses were finally identified which reported on all data items of the survey (i.e. no missing values of all survey questions), and had non-zero total financial expenditures during the period of the survey.

4.2. Measures

For the first hypothesis, the scope of IP appropriability regimes (*IP_Scope*) employed by the focal business was measured by the sum of responses to eight related questions drawn from the survey. This construct combined both formal and informal methods of IP protection, namely ‘patents’, ‘registration of design’, ‘copyright or trademark’, ‘other formal methods’, and ‘secrecy (including electronic protection methods)’, ‘complexity of product design’, ‘making frequent and rapid changes to the good or service’, and ‘other informal methods’. Every business was asked

whether it had utilized each appropriability regime component, answering with a binary variable, 1 for yes and 0 for no. These responses were aggregated to construct the overall scope of the appropriability regimes within the focal business. Accordingly, this aggregate ordinal measure ranges from 0-8.

For the second hypothesis, the eight formal and informal protection mechanisms stated above were respectively employed as dependent variables, namely formal methods — patent (*Patent*), registration of design (*Registration*), copyright or trademark (*Copyright*), and other formal methods (*Other*); and informal methods — secrecy (*Secrecy*), complexity of product design (*Complexity*), making frequent and rapid changes to the good or service (*Speed*), and other informal methods (*Other*). All of these variables are dichotomous and were coded with the value of 1 if the business had adopted this specific method and 0 otherwise.

The three measures of the *degree of openness* were constructed as follows. The *IABS* listed 11 key knowledge sources that contribute to the development of innovations, namely customers, suppliers, consultants, competitors, universities, government agencies, private research institutions, commercial laboratories, professional conferences, websites and journals, and other sources of ideas or information. These in turn fall into three main categories — market sources, institutional sources and other sources. Each business was asked to indicate the sources it had used. By combining the respective binary responses to the use of these eleven sources, an ordinal scale of the breadth of external sources (*Sources*) was developed, taking the value of 0 with no external sources used and 11 with all of these potential sources used.

Inter-organizational Collaboration (*Collaboration*) was measured by summing the binary responses to six survey questions regarding whether the business had actively engaged in any types of collaboration (to develop new products/services or new processes). These activities involved joint marketing or distribution, joint manufacturing, joint research and development, other joint ventures, licensing agreements, or other forms of collaboration. Each question formed a binary variable taking the value of 1 when the business indicated that it had used this type of collaboration and 0 otherwise. Therefore, the aggregate ordinal measure for collaboration ranges from 0 to 6.

Technology Purchase (*Techbuyin*) was measured by the proportion of the estimated value of machinery, equipment, licenses, patents and other intellectual property externally acquired to develop new goods/services or processes to the total expenditure of the business in the calendar year 2003. This is a continuous variable ranging from 0 to 1.

It has been noted that the construct of the dependent variable for the first hypothesis (i.e. the scope of IP appropriability regimes) may involve some licensing agreements which are also present in the measures of independent variables such as inter-organizational collaboration and technology purchase. It is believed that this will not affect the validity of this study's statistical analysis because although similarly termed, they are sourced from two distinct questions in the survey. The licensing-in arrangements involved in the independent variable measures mainly refer to buying in externally developed technologies which are embodied in licenses — a typical approach to acquiring exogenous knowledge from external environment [12]; while the licensing arrangements in the dependent variable measure relate to the licensing of the organization's

internal innovation output — typically a formal appropriability regime which protects knowledge internally generated [62].

In terms of control variables, this study controlled for the role of internal R&D in terms of two proxy measures namely 'R&D expenditure' and 'investment in internal human capital'. It has been shown by prior research that there was a complementary and interactive relationship between endogenous R&D and the acquisition of exogenous knowledge and technology [29],[36]. R&D Expenditure (*R&D*) was calculated based on the estimated expenditure on research & development activities of new and changed goods (/services) or processes controlled by the total expenditure of the focal business. This provided a continuous measure of the relative importance of financial investment in internal research and development. The investment in human capital of the focal business (*Staffing*) was constructed by combining three main survey questions with regard to whether the business had employed new skilled staff, whether it had employed new graduates, and whether it had employed academic or research staff. Additionally, another two common control variables related to some basic attributes of a business — firm size and industry type were also included. Firm size (*Size*) was released by the ABS as a categorical variable (on a 1-3 scale: 1 for 5-19 persons, 2 for 20-99 persons, 3 for 100 or more persons). Based on the ANZSIC industry codes, an industry dummy (*Industry*) was included as well with the value of 1 if the business was in a manufacturing-focused industry (i.e. mining; manufacturing; electricity, gas and water supply; construction) and 0 for a more service-focused category (i.e. wholesale trade; retail trade; accommodation, cafes and restaurants; transport and storage; communication services; finance and

insurance; property and business services; cultural and recreational services). This control variable is important to address the current research focus on open innovation beyond those high-technology industries [4],[5].

The main limitations of measures relate to the inability to capture the depth dimension of openness, as this study was confined to the variables that provided by the secondary dataset *IABS*. Similarly, how appropriability regimes develop over time could not be assessed due to the lack of longitudinal data. Nevertheless, the large sample size across a range of industry sectors with relevant data on the use of various appropriability regimes provided a useful entry point into considering the oft-ignored area of appropriability regimes in the context of open innovation.

4.3. Statistical Models and Modelling Results

The descriptive statistics of variables are shown in Table 1. In relation to Hypothesis 1, the nature of dependent variable *IP_Scope* is very close to a non-negative count variable with over-dispersion (i.e. the variance of this variable is much larger than its mean as shown in Table 1). Thus a Negative Binomial Regression model was employed for this analysis in Stata (this has been shown to be superior to Poisson and OLS regression models for data of this type) [63]. A hierarchical form was adopted in the study, meaning only control variables were included in the basic model, with the three measures of the degree of openness *Sources*, *Collaboration* and *Techbuyin* and their squared terms entered in a stepwise way to examine their inverted U-shape effects. An inverted U-shape effect is typically demonstrated by a positive and significant coefficient of the focal independent variable and a significant and negative coefficient of its

quadratic (squared) term, indicating its declining marginal effect on the dependent variable [64],[65]. For Hypothesis 2, as all eight dependent variables are dichotomous, a Binary Logistic Regression was employed for each model in SPSS.

Table 1: Means, Standard Deviations and Correlations

Variable	Mean	S.D.	1	2	3	4	5	6	7
1. IP_Scope	0.678	1.076							
2. Sources	2.384	2.096	.32**						
3. Collaboration	0.335	0.925	.33**	.28**					
4. Techbuyin	0.009	0.048	.09**	.09**	.11**				
5. R&D	0.012	0.069	.13**	.07**	.09**	.08**			
6. Staffing	0.494	0.927	.35**	.40**	.26**	.09**	.09**		
7. Size	1.739	0.793	.28**	.18**	.14**	-.01	-.03*	.35**	
8. Industry	0.423	0.494	.09**	-.02	.01	.05**	.03*	-.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 models in Table 2 aimed to test Hypothesis 1 namely how the degree of openness (measured by the breadth of external sources, the scope of inter-organizational collaboration and the extent of technology buy-in activities) explains the scope of the overall appropriation mechanisms employed by the focal firms. All these models showed a high significance of the overall model fit (indicated by the significance level of Chi-square all < .001). The results provided strong support for the Hypothesis 1 because: first the coefficients of the linear forms of all three measures, namely *Sources*, *Collaboration* and *Techbuyin*, were positive and highly significant (p<

.001 for *Sources* and *Collaboration*, and p< .05 for *Techbuyin*), indicating that external sources, inter-organizational collaborations and technology purchase activities are all important explanatory factors in determining the scope of appropriability regimes employed by firms. While the values of Pseudo R^2 were provided for all models in this paper, they cannot be used for a direct comparison between different types of models in Table 2 and 3 [66]. However, for the models shown in Table 2, the increased Pseudo R^2 provided a general indication that with the linear forms of the three measures entered, the second model provided a heightened explanation of the relationship between variables than the first model with only control variables.

Secondly, the coefficients of $Sources^2$ and $Collaboration^2$ were both negative and significant (p< .001), with a concomitant significant improvement in the explanatory/predictive power of the model (indicated by a further increase in the Pseudo R^2) after the introduction of the squared terms. However, the $Techbuyin^2$ was not significant (p> .10), indicating this measure of the degree of openness only had a linear effect on the scope of appropriability regimes employed by firms.

Therefore, based on the sample of this study, Hypothesis 1 asserting that the degree of openness is curvilinear (taking an inverted U-shape) in its relationship to the scope of a firm's appropriability regimes was supported for two indicators of openness.

Table 2: Negative Binomial Regression for Scope of IP Appropriability Regimes

Control Variables & Independent Variables ↓	**DV — Scope of IP Appropriability Regimes** (*IP_Scope*)		
(Constant)	-1.621 ***	-1.913 ***	-2.133 ***
Firm Size (*Size*)	0.421 ***	0.391 ***	0.389 ***
Industry Dummy (*Industry*)	0.383 ***	0.369 ***	0.371 ***

R&D Expenditure (*R&D*)	2.225 ***	1.667 ***	1.528 ***
Human Capital (*Staffing*)	0.299 ***	0.153 ***	0.158 ***
The Degree of Openness			
Scope of External Sources (*Sources*)		0.122 ***	0.298 ***
Inter-organizational Collaboration (*Collaboration*)		0.201 ***	0.429 ***
Technology Purchase (*Techbuyin*)		0.949 *	1.841 *
The Degree of Openness Squared			
Scope of External Sources Squared ($Sources^2$)			-0.025 ***
Inter-organizational Collaboration Squared ($Collaboration^2$)			-0.055 ***
Technology Purchase Squared ($Techbuyin^2$)			-1.974
LR Chi-square	642.52 ***	935.53 ***	1012.59 ***
Log likelihood	- 4568.275	- 4421.769	- 4383.240
Pseudo R^2	0.0657	0.0957	0.1035

n=4322

$^+$ p < .10, * p < .05, ** p < .01, *** p < .001

It was surmised that the reason technology purchase did not present a declining marginal effect as per the other two measures of openness may be related to the specific characteristics associated with technology buy-in activities. Whereas the inter-organizational collaborations and knowledge sources available to firms can be encapsulated into a limited number of categories (such as the 6 types of collaborations and the 11 sources of knowledge as previously stated), the nature of technology acquired from the outside could be tremendously diverse. When dealing with the increase in the variety of technology purchased, it may be less likely for firms to narrow their selection of certain appropriability regimes. This is mainly due to the protection effects emanating from the nature of underlying IP. IP relating to a specific technology may already have been designated by the seller or it may be purchased in a form which is best suited to a particular

appropriability regime. Therefore, as more technologies are purchased from outside the firm, the number of various IP protection instruments employed is likely to keep increasing in a linear, or at least monotonic, fashion.

Table 3 illustrates the results regarding Hypothesis 2 proposing that the degree of openness will be positively related to the formal use of appropriability regimes and negatively related to the use of informal appropriability regimes. The possibility of multicollinearity has been assessed and discounted, as the Variance Inflation Factors (VIFs) are all less than 1.5 (with the maximum VIF 1.352, and the average 1.135), thus within the generally acceptable level of less than 5 and also below the general threshold 2.5 for logistic regression models [67].

All these eight models had a significant overall model fit (indicated by the significance level of Chi-square all < .001). Although there is no close analogous statistic in logistic regressions to an OLS R^2, Nagelkerke R^2 is one of the most-reported R-squared estimates in SPSS as an approximation [66]. With the exception of the two models reporting 'other formal (IP protection) methods' and 'other informal (IP protection) methods', all models relating to the main IP protection methods showed a moderately strong relationship between their respective independent variables and dependent variables (indicated by the Nagelkerke R^2 ranging from 0.141 to 0.207 in these six models).

Table 3: Binary Logistic Regression for Specific IP Appropriability Regimes

IVs & CVs ↓	**DVs — Specific IP Appropriability Regimes**	
IV —	**Formal**	**Informal**

The Degree of Openness	***Patent*** **(*odds ratios*)**	***Registration*** **(*odds ratios*)**	***Copyright*** **(*odds ratios*)**	***Other*** **(*odds ratios*)**	***Secrecy*** **(*odds ratios*)**	***Complexity*** **(*odds ratios*)**	***Speed*** **(*odds ratios*)**	***Other*** **(*odds ratios*)**
External Sources (*Sources*)	0.043	0.092 *	0.121***	0.190 ***	0.182 ***	0.153 ***	0.125 **	0.203 ***
	(*1.044*)	(*1.096*)	(*1.129*)	(*1.209*)	(*1.199*)	(*1.165*)	(*1.133*)	(*1.225*)
Collaboration (*Collaboration*)	0.251 ***	0.211 ***	0.259 ***	0.303 ***	0.310 ***	0.239 ***	0.332 ***	0.047
	(*1.285*)	(*1.235*)	(*1.296*)	(*1.354*)	(*1.364*)	(*1.269*)	(*1.394*)	(*1.048*)
Technology Purchase (*Techbuyin*)	-0.363	1.574	0.574	-1.716	1.469 *	1.609 *	2.705 **	-1.010
	(*0.696*)	(*4.828*)	(*1.776*)	(*.180*)	(*4.346*)	(*4.997*)	(*14.948*)	(*.364*)
Control Variables								
Firm Size (*Size*)	0.966 ***	0.649 ***	0.639 ***	0.284 *	0.341 ***	0.239 **	0.181 +	0.243 *
Industry Dummy (*Industry*)	1.381 ***	1.043 ***	0.339 ***	-0.566 **	0.012	1.198 ***	0.267	0.044
R&D Expenditure (*R&D*)	2.332 ***	0.510	1.669 **	1.409	1.377 **	2.391 ***	2.458 ***	0.978
Human Capital (*Staffing*)	0.241 ***	0.263 ***	0.170 ***	-0.087	0.265 ***	0.281 ***	0.317 ***	0.009
Constant	-5.770 ***	-5.453 ***	-3.662 ***	-4.667 ***	-2.645 ***	-4.274 ***	-4.554 ***	-4.629 ***
Chi-square	367.517 ***	195.075 ***	404.769 ***	68.758 ***	527.783 ***	321.957 ***	180.188 ***	39.473 ***
-2 Log likelihood	1801.378	1424.786	3303.150	956.037	4131.159	2199.581	1291.294	1071.508
Nagelkerke R^2	0.207	0.141	0.155	0.075	0.174	0.162	0.142	0.040

+ p < .10, * p < .05, ** p < .01, *** p < .001

The results of these eight models were almost contrary to the Hypothesis 2. The insignificance of external sources (*Source*) for the method of patent, and the insignificant effect of technology purchase (*Techbuyin*) for all three main formal methods (i.e. patent, registration, and copyright) demonstrated that the degree of openness (constructed by the three variables *Sources*, *Collaboration*, and *Techbuyin*) was not significantly associated with the use of formal appropriability regimes. On the other hand, all these three measures were significantly and

positively related to all three main informal appropriability regimes (i.e. secrecy, complexity of product design, and rapid and frequent changes to the product/service).

Odds ratios for each independent variable were also reported in Table 3 to better interpret the effect size in logistic regressions. Odds ratios clearly demonstrate the relative importance of an independent variable in terms of its effect on the dependent variable's odds [66]. In these models, all independent variables with significant coefficients had their odds ratios > 1. An odds ratio greater than 1, for example, of 1.285 in the first model indicates that a one unit increase in the independent variable (i.e. measure of the degree of openness — *Collaboration*) leads to a 1.285 unit increase in the odds of the outcome occurring (namely, increasing the likelihood of using *Patent* as a protection method about 1.3 times) [66].

The values of odds ratios, consistent with the statistical implications of coefficients, indicated an increase in the degree of openness did not result in the corresponding increased likelihood of the use of formal IP regimes. However, such an increase did lead firms to a greater propensity to use the three main informal regimes, particularly for the variable Technology Purchase (*Techbuyin*), It was evident that firms who tend to purchase more external technology are much more likely to use informal mechanisms than formal methods to protect their own innovations, such as through controlling the firm secrecy, increasing the complexity of product design and making rapid improvements in their products/services and processes (probably with the contribution of the externally purchased technology).

To summarize, the values and significance levels of coefficients, as well as the odds ratios,

all indicated that open innovators are likely to employ more informal appropriability regimes, instead of more formal regimes, as the open innovation literature would suggest.

5. Discussion and Conclusions

A key question in the open innovation arena relates to the paradox of how firms are able to access external knowledge without negatively affecting their own competitiveness due to the opening of some of their core knowledge to external partners. It is in this context that this study sought to investigate the role of openness in respect of the appropriation regimes firms pursue via an empirical analysis of 4,322 Australian businesses.

This study provided some noteworthy findings. First, the results of this study revealed a complexity in the relationship between the breadth of external knowledge sources, the scope of inter-organizational collaborations that a firm is involved with, and the variety of appropriability regimes it utilizes. The findings showed that firms employ increasingly complex and multifaceted appropriability regime arrangements when operating in an open innovation mode, with a propensity to flattening the scope of the regimes (with an eventual decline in this scope) as the degree of openness increases. This declining marginal utilization can be attributed to firms minimizing the collective risks and inefficiencies of managing multiple appropriability regimes by investing in a more limited set of options.

The open innovation - appropriation relationship has not been clear either theoretically or empirically in the extant literature. This finding regarding the degree of openness and its curvilinear relationship to the scope of appropriability regimes employed provided new insight

into the traditional understanding of firms' tendency to protect their knowledge through appropriability regimes. In the open innovation context, firms tend to respond to the increasing variety of external knowledge sources and the greater diversity of external partners with non-linear and complex behaviours to manage their intellectual property portfolio.

As such, this study is an important contribution to the deepening of our understanding of the behaviours and strategies of firms engaged in open innovation practices. The statistical results based upon Hypothesis 2 provided some challenges for the adoption of open innovation. They tended to show that open innovators adopt more informal appropriation and IP protection mechanisms, potentially blocking necessary knowledge spillovers to external partners. This in turn hinders knowledge exchange which, as suggested by open innovation assumptions, is supposed to be facilitated based on reciprocity. This finding reflected some concerns of firms that are inclined to become open innovators but face the 'paradox of openness'. It was also consistent with some doubts about the theoretical foundations of the open innovation paradigm. Specifically, some recent research has questioned the feasibility of gaining returns through open flows and shared knowledge [68],[69].

Corralling the royalty rights to innovation-based products or processes is at the heart of traditional understandings of IP appropriation. This classical view of appropriability underscores the importance of limiting a firm's spillovers of important knowledge to the external environment to capture values from innovations [43],[69]. Open innovation, on the other hand, suggests that, in contrast to the closed innovation within which knowledge flows are largely avoided, firms

operating an open innovation strategy need to attempt to purposively enable the disclosure of knowledge and technology, in order to secure profits from openness [1],[21].

However, in practice, controlling the balance between purposive knowledge disclosure and unintended knowledge spillovers is extremely challenging [66],[9]. This has been influenced by the higher rates of mobility of skilled workers which in turn facilitates the flow of their tacitly held knowledge [12],[20], and increasing globalization that advances the transfer of technology embodied in products within boundaryless markets [21],[8]. Enhanced unintended knowledge flows, along with increased voluntary knowledge disclosure, tend to increase knowledge outflows, including outflows of sensitive knowledge and valuable firm technologies [69].

These circumstances could explain one of the main threats presented to most open innovators, namely the risks associated with the unintended leakage of their core resources and knowledge. According to the resource-based view, resources should be rare and imperfectly imitable if they are to sustain their competitive value [42]. When making the knowledge boundaries of the firm more permeable, the risks of open innovation might reduce the rareness and inimitability of a firm's core resources and further weaken its competitive position [42]. The competitive strength for firms adopting an open innovation strategy has been thereby questioned [68]. Dahlander and Gann [12] clearly note this as a potential downside of open innovation. With the fear that the benefits from open innovation may not successfully outweigh the negative effects associated with weaker competitive heterogeneity, firms may tend to resort to more elaborate appropriability regimes as an effective source of competitive differentiation.

This might impede the essence of open innovation. As Schmidt [21] has suggested, the open innovation strategy might become simply a ‘marketing stunt’ if firms claim that they are open while not increasing any actual knowledge outflows to other firms. The necessity for both ‘give and take’ within the open relationship leads to a high degree of knowledge sharing. Knowledge receipt and supply are innately intertwined and concurrent, as each ‘take’ by an organization is essentially generated by a reciprocal ‘give’ activity from some other organization [4]. Without this foundation, fewer and fewer firms would continue to supply free and open knowledge, leading to a vicious cycle where reciprocity, which is the core of open innovation, might slowly decline. This points to some conjecture about open innovation’s potential.

On the other hand, in order to expressly benefit from openness, firms, in the long run, still need to gradually reduce the control on their intellectual property, particularly in terms of informal appropriability regimes, to promote necessary knowledge spillovers and exchanges. There are valuable managerial implications derived from this research for practitioners of open innovation. In order to minimize the potential risks of weakened competitive advantages, great care must be taken in keeping an appropriate trade-off between knowledge sharing and knowledge protection. This key challenge could be partially resolved by keeping evaluation of net knowledge flows, adjusting the portfolio of appropriability regimes accordingly, and controlling relationships with external partners carefully to ensure a balanced ‘give and take’ relationship. It is expected that a full awareness of the potential downsides of openness can help open innovators gradually to better

manage these challenges by developing firm-specific strategies to largely secure long-term benefits form openness.

These complex and perplexing propositions relating to the future direction of open innovation demonstrate an interesting area which can be further explored with more recent empirical data and longitudinal analysis in the future research.

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