Managing Knowledge Flows through Appropriation and Learning Strategies *

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Abstract

In this paper, the management of outgoing and incoming knowledge is modelled as part of the firm's profit-seeking strategy. Firms stem their outflow of commercially-sensitive knowledge through appropriation mechanisms such as patents and secrecy and stimulate inflows of commercially-valuable knowledge through networking, attending conferences and other forms of external interaction. It is probable, however, that some learning styles undermine some appropriation mechanisms. For instance, recent research on the "paradox of openness" highlights the conflict between firms' openness and their ability to appropriate innovation profits. We use survey data from over 600 Australian firms to examine this paradox and other effects of firms' management of knowledge flows such as the complementarity between patents and secrecy.

1. Introduction

Knowledge management is widely regarded as playing an important role in creating and developing firms' competitive advantage and profits (see, for example, Winter 1987; Grant 1996). Accordingly, managing the flow (incoming and outgoing) of commercially-sensitive knowledge is one of the most important functions the management of a firm performs. This involves a difficult balancing act: on the one hand, firms can capture important knowledge by observing, imitating and interacting with other firms. At the same time, however, such interaction may undermine their competitive advantage since some knowledge inadvertently spills over to rival firms. The crux of the problem is that firms cannot constrain losses realised through the leakage of knowledge without impinging on how much knowledge flows into the firm. For example, adopting an aggressive patenting stance may send a signal to rival firms not to share information. In this paper, we examine the relationship between firms' appropriation strategy and how they gather knowledge using data from a survey of over 600 Australian firms from 2001 to 2004.

The paper is organised as follows. In the following section we discuss the nexus between appropriation and learning strategies. Section 3 describes the survey questionnaire and provides a descriptive analysis of the survey responses. We then compare the results from our survey with other similar innovation surveys. In Section 4, we outline the empirical model used to examine the relationship between learning and appropriability. Section 5 discusses the results of the estimation. We close in Section 6 with some conclusions.

2. Appropriation and Learning

Without the means to appropriate the returns from investment, firms will not invest. As many benefits associated with innovation and information goods easily (and involuntarily) spillover to rival firms (Arrow 1962), firms need an appropriation strategy to recoup their investments into innovation activities. The creation of new knowledge does not occur in a vacuum however, and therefore firms' learning strategies and the integration of new knowledge into the production chain are parallel themes (see Veugelers and Cassiman 1999

on whether firms choose to "make" or "buy" new knowledge). The goal of a profit-seeking firm will be to minimise outgoing-knowledge flows while maximising incoming-knowledge flows.

Common appropriation mechanisms range from legally-codified titles through to informal methods. Intellectual property rights such as patents and trade marks – which are used as an aid protecting innovators from imitation – have incomplete and irregular coverage across industries and technology areas.[1] As a result, other appropriability mechanisms – such as secrecy and organisational know-how – are also often used. These mechanisms can be used either to complement patenting – where some elements of the invention are patented and others are kept secret (see Graham 2004; Arora 1997) – or to substitute for patenting. Following the seminal work of Levin *et al*. (1987), it is well-known that the effectiveness of appropriability mechanisms varies across industries.

The effectiveness of an appropriation mechanism is likely to be affected by the underlying nature of knowledge: that is, whether the knowledge is tacit or has been codified.[2] Inventions which are based on codified knowledge, for example, might be better protected using patents, while inventions based on tacit knowledge may be more suitable to protection offered by trade secrecy. Moreover, returns from investing into tacit technology may be easier to appropriate since the costs of imitation may equal (or be close to) the cost of invention (Webster and Jensen 2006). Saviotti (1998) argues that there is a dynamic component to the relationship between appropriability and knowledge: as technology matures (and the degree of codification increases), the ability to appropriate innovation profits decreases. The available empirical evidence seems to support the contention that industries which rely on product inventions based on codifiable knowledge (such as the pharmaceutical industry) are much more likely to find patents an effective appropriation mechanism. On the other hand, industries relying on tacit knowledge are more likely to

[1] This is partly due to the fact that it is difficult to unambiguously delineate the boundaries of a given innovation in a written legal document, particularly with regard to patents (see Lemley and Shapiro 2005).

[2] As Cowan *et al.* (2000) note, the tacit-codifiable knowledge dichotomy is simplistic and unrealistic since most knowledge is *potentially* codifiable. Since the costs of codification are often quite high, not all knowledge which is codifiable will in fact be codified. However, the dichotomy is a useful device with which to explain some of the observed inter-industry differences in the effectiveness of appropriation strategies.

find trade secrets or organisational know-how more effective appropriation mechanisms (Harabi 1997; Arundel 2001).

With respect to knowledge creation, firms may use market-based transactions – such as licensing, company takeover, or headhunting – to acquire knowledge or know-how or they may rely on their own investments in training including learning-by-doing and R&D. In both instances, the firm's absorptive capacity (i.e. its knowledge stock) plays a key role (Cohen and Levinthal 1989). Many recent studies have alluded to the fact that firms are becoming more reliant on external sources in their innovative activities (see Chesbrough 2003, for example).[3] However, adopting such an open strategy through cooperating or sharing information with rivals creates a fundamental problem: firms that use external sources to create knowledge must also try and keep some of the knowledge private in order appropriate the returns from the knowledge created. Laursen and Salter (2005) recently referred to this relationship between learning and appropriability as the "paradox of openness". This tension was first recognised by Nelson and Winter (1982) and has been studied empirically in other papers such as Cassiman and Veugelers (2002) and Heiman and Nickerson (2004).[4]

As with appropriation mechanisms, the underlying nature of the knowledge may also have implications for firms' learning strategies since it may be that innovations are often made (rather than bought) if the knowledge is tacit and specific rather than universal and public, since the former is much harder to buy than the latter (Dosi 1988). Supporting this contention, Brusoni *et al.* (2005) find evidence that firms in high-tech sectors are most likely to rely on codified sources of knowledge. Thus, both the firm's learning and appropriability strategies are integrally connected to the underlying nature of the knowledge (Cohendet and Meyer-Krahmer 2001).

There are two broad types of learning style. Firms may adopt what we define here as "closed" learning styles – where they rely on being able to collect information through

[3] Other recent research suggests that there is a robust (curvilinear) relationship between openness and innovative performance (see Laursen and Salter 2006).

[4] Teece and Pisano (1994) considered a slightly different issue: whether there is a relationship between the nature of incentives and appropriability. They argue that high powered incentives may adversely affect cooperative learning within firms since individuals will behave opportunistically, often at the expense of others on their team.

formal information exchanges such as patent disclosures, blue-prints and manuals – in order to create codified knowledge. Creators of tacit knowledge, on the other hand, may need to rely on "open" learning styles – such as networks with competitors – in order to capture important synergies.

We expect, *a priori*, that both the nature of knowledge and the culture of openness affect how well different styles of appropriation and learning may coexist. In this paper, we explore the nexus between firms' appropriation and learning strategies using data collected from a survey of over 600 for-profit Australian firms conducted annually from 2001 to 2004 on various aspects of their innovative activities. By doing so, we provide empirical insights into three important research issues. First, we examine the determinants of firms' appropriation strategies with a view to explaining the underlying causes of inter-industry differences in the effectiveness of appropriation mechanisms. Second, we search for evidence of the "paradox of openness" by considering whether those firms who utilise open learning strategies are more likely to use trade secrets than patents to appropriate returns. Third, we examine the complementarity of different appropriation and learning strategies.

3. Data and Descriptive Analysis

The data used to analyse the relationship between learning and appropriability were collected from annual surveys of managers of the largest Australian firms (as measured by total revenue) from the IBISWorld firm database. Approximately 5000 surveys were mailed out in total between 2001 and 2004, with 950 useable surveys returned (a response rate of 19 per cent). For our analysis, however, only 700 to 850 surveys were complete. Descriptive statistics are presented in Table 1 on the major industry categories and employment size for the organisations in our sample. Most organisations (26.2%) were located in manufacturing, with the next highest proportion in finance and insurance (12.0%), property and business services (7.2%), and wholesale (11.7%) and retail (5.9%) trade. The distribution of responses across characteristics does not differ markedly from the initial selected population, implying that the responses should are not biased towards a particular industry.

Table 1: Characteristics of Surveyed Organisations, Australia 2001-2004

Industry Group	Respondents (%)	Population (%)
Agriculture, Forestry & Fishing	1.0	0.7
Mining	3.1	2.8
Manufacturing	26.2	24.1
Electricity, Gas & Water Supply	4.5	6.8
Construction	3.2	4.5
Wholesale Trade	11.7	11.3
Retail Trade	5.0	5.9
Accommodation, Cafes & Restaurants	0.5	0.5
Transport & Storage	3.9	3.8
Communication Services	0.3	0.2
Finance & Insurance	12.0	14.2
Property & Business Services	7.2	10.6
Government Administration & Defence	0.9	1.2
Education	4.4	3.8
Health & Community Services	3.8	4.5
Cultural & Recreational Services	2.3	3.3
Personal & Other Services	1.7	1.9
Missing	8.2	
Total	*100.0*	*100.0*
Employment Size		
Under 200	11.2	12.2
200 to under 500	17.7	20.4
500 to under 1000	19.8	19.8
1000 to under 5000	39.0	38.6
Over 5000	12.3	9.0
Total	*100.0*	*100.0*

Source: Melbourne Institute Business Survey 2001, 2002, 2003, and 2004.

The survey was addressed to senior managers with responsibility for innovation policies. Like other similar innovation surveys, the questions used a seven-point Likert scale with the anchors 1 and 7. Such perceptual measures permit comparisons across different organisations and industries and are easy to collect because they place fewer burdens on respondents than administrative or factual entries. The questionnaire asked a range of questions relating to market conditions in the industry the firm operates in (volatile, easy to enter), the firm's learning style (open or closed), the effectiveness of a range of appropriability mechanisms (e.g. patents, secrets, lead time) and the firm's competitive strategy (price versus quality). Other firm-specific characteristics (size, industry) were collected by matching the survey data to IBISWorld data.

3.1 Appropriation Mechanisms

Firms were asked in the survey to assess the relative effectiveness, on the Likert scale of one to seven, of five mechanisms used to appropriate the benefits from new or improved products and processes. These mechanisms were: patents; secrecy; lead time (including moving quickly down the learning curve); control over the distribution process, brand names and marketing; and organisational know-how, capabilities[5] and production complexity. The average rating of these appropriability mechanisms is presented in Table 2, along with comparable results from previous studies of this ilk by Levin *et al*. (1987) and Harabi (1995).[6] It shows that know-how was the highest-rated form of appropriability, closely followed by distribution and brand names.

Table 2: Rated Effectiveness[a] of Appropriation Mechanisms, Australia, US and Switzerland

	Melbourne Institute Business Survey		**Yale Survey**		**Swiss Survey**	
Appropriation Mechanism	*Australia, 2001-2004*		*US, 1983*		*Switzerland, 1988*	
	Mean Products	Mean Processes	Mean Products	Mean Processes	Mean Products	Mean Processes
Patents	3.41	2.90	4.33	3.52	3.44	2.76
Secrecy	3.56	3.52	3.57	4.31	3.25	3.60
Lead time[b]	4.24	4.20	5.41	5.11	5.37	5.63
Moving quickly down the learning curve			5.09	5.02	4.56	4.42
Distribution & brand names[c]	4.50	4.15				
Know-how[d]	4.82	4.75				
Sales and service efforts			5.6	4.55	5.2	5.7
Researchers	Jensen and Webster		Levin *et al.*		Harabi	
Sample size	850		650		358	

Note: [a] Scale is based on a Likert scale with anchors 1 (= very ineffective) and 7 (=very effective). [b] For Australia, Lead time and Moving quickly down the learning curve have been combined. [c] Control over distribution and Brand name and marketing. [d] Organisation know-how, capabilities and production complexity.

Similar to the other two studies (and the follow-up study by Cohen *et al.* 2000), patents are reported as being relatively weak appropriation tools. There was some variation in the

[5] Capabilities are the firm's ability to appropriate, integrate and organise internal skills to meet the requirements of the market.

[6] Studies such as Cohen *et al.* (2000) which *rank* effectiveness are not strictly comparable to the studies mentioned here which *rate* effectiveness.

relative effectiveness of each appropriation strategy across industry groups in our data. In particular, know-how was the most commonly-cited appropriation strategy for mining; manufacturing; electricity, gas and water; construction and property and business services. For the remaining service industries, know-how was second to distribution and brand names.

3.2 Learning Styles

The survey also asked questions about the importance of different learning styles which we categorised as networks (both formal collaboration and informal contact); suppliers and customers; licensed technologies; publications (including patent disclosures and technical meetings); and R&D (including reverse engineering). We classified both networks and suppliers/customers as open learning styles since they involve reciprocal engagement with other people. The other three styles of learning are available remotely through institutional or market brokers, or, are bought for a fair price through the market and we classified these as closed styles. These three learning styles involve disembodied knowledge flows where there is no non-pecuniary reciprocity between parties.

Table 3: Rated Effectiveness[a] of Learning Styles, Australia and US

	Melbourne Institute Business Survey	**Yale Survey**	
Learning Style	*Australia, 2001-2004*	*US, 1983*	
	Mean Products and Processes	Mean Products	Mean Processes
OPEN			
Networks[b]	4.83	4.07	4.07
Suppliers & customers[c]	4.15		
CLOSED			
Licensing technologies	2.94	4.62	4.58
Publications[d]	3.46	4.01	3.88
R&D[e]	3.41	4.92	4.42
Researchers	Jensen and Webster	Levin *et al.*	
Sample	850	650	

Note: [a] Scale is based on a Likert scale with anchors 1 (= very ineffective) and 7 (= very effective); [b] Informal networks with other organisations and Formal cooperation/networks with other organisations; [c] Lead suppliers and customers; [d] Patent disclosures and Publications or technical meetings; [e] In-house R&D and Reverse engineering.

From Table 3 it can be seen that, on average, firms rate the first two open learning styles as more effective than the last three closed styles. Among the former, networks with other organisations was the more highly rated source of information, while among the latter, the most commonly-rated learning source was publications (including technical meetings and patent disclosures). For comparison, we have listed the responses from the Levin *et al*. survey in Table 3. Their findings however, show little bearing to the Australian list. Learning styles in our survey show little variation across firms by either size or industry (although these results are not presented here).

4. Modelling Appropriation and Learning Strategies

To analyse the relationship between firms' choices of appropriation and learning strategy, we assume that the profit-maximising firm seeks to maximise the value of this knowledge subject to its costs of acquisition. Firms subsequently manage their knowledge flows through their knowledge management strategy, *S*. The stock of knowledge, *K*, may be represented as:

$$K = f(S) + K_{-1} \tag{1}$$

Let there be *n* appropriation and learning components that make up the overall strategy. The knowledge-management strategy can be represented as:

$$f(S) = \sum_{i=1}^{n} S_i^{\alpha_i} + \sum_{i,j=1}^{n} \beta_{ij} S_i S_j \qquad i, j = n, i \neq j \tag{2}$$

where S_i and S_j are units of commercially-sensitive knowledge withheld by the firms through a specific appropriation mechanism or learning style, respectively. The interaction term in (2) allows for possible synergies of the combined strategies. α is the coefficient on each dimension of the knowledge management strategy and β is the set of coefficients on the interaction terms: $\beta > 0$ when synergies exist, but $\beta < 0$ if the two strategies effectively sabotage each other. The profits equation is:

$$\Pi = v\left(\sum_{i=1}^{n} S_i^{\alpha_i} + \sum_{i,j=1}^{n} \beta_{ij} S_i S_j\right) - \sum_{i=1}^{n} c_i S_i \qquad (3)$$

where *v* represents the value of the knowledge units to the firm and c_i is the unit cost of increasing the stock of knowledge through each knowledge management strategy. We can solve this as an unconstrained profit-maximising problem to get:

$$S_i^* = (\alpha_i v)^{\sigma_i} + \sum_{i,j=1}^{n} \beta_{ij} S_j \alpha^{\sigma_i} c_i^{-\sigma_i - 1} \sigma_i v^{1+\sigma_i} \qquad \forall i, j \text{ for } i \neq j \qquad (4)$$

using the approximation $(1+x)^y \approx 1 + xy$[7] and where $\sigma_i = -1/(\alpha_i - 1)$.

There are three types of interaction effects that we are interested in: complementarity between appropriation mechanisms, complementarity between learning styles, and complementarity across appropriation and learning strategies. In the simplest case, where there is a single combined appropriation mechanism, (S_A) – where $S_A = \sum_{i=1}^{a} S_i$ and *a* is a distinct appropriation mechanism – and a single combined form of learning, (S_L) – where $S_L = \sum_{j=1}^{l} S_j$ and *l* is a distinct learning style – we have:

$$K = S_A^{\alpha_A} + S_L^{\alpha_L} + \beta_{AL} S_A S_L + K_{-1} \qquad (5)$$

We can introduce further complexity by disaggregating learning into open and closed styles, (S_o, S_c), such that $S_L = S_o + S_c$ – and this produces the following knowledge function:

$$K = S_A^{\alpha_A} + S_o^{\alpha_o} + S_c^{\alpha_c} + \beta_{Ao} S_A S_o + \beta_{Ac} S_A S_c + \beta_{oc} S_o S_c + K_{-1} \qquad (6)$$

For the case where we have 2 appropriation mechanisms – say, patents and secrecy (S_p, S_s) such that $S_A = S_p + S_s$ – but only one combined form of learning (S_L), we have:

$$K = S_p^{\alpha_p} + S_s^{\alpha_s} + S_L^{\alpha_L} + \beta_{pL} S_p S_L + \beta_{sL} S_s S_L + \beta_{ps} S_p S_s + K_{-1} \qquad (7)$$

[7] This approximation holds over the range $0 \leq x, y \leq 1$.

Finally, the most disaggregated model assumes there are 2 appropriation mechanisms (S_p, S_s) and 2 learning styles (S_o, S_c). This gives a knowledge stock of:

$$K = S_p^{\alpha_p} + S_s^{\alpha_s} + S_o^{\alpha_o} + S_c^{\alpha_c} + \beta_{ps}S_pS_s + \beta_{po}S_pS_o + \beta_{pc}S_pS_c + \beta_{so}S_sS_o + \beta_{sc}S_sS_c + \beta_{oc}S_oS_c + K_{-1} \quad (8)$$

As discussed in the previous section, our survey reports measures of the *effectiveness* of appropriating investments in new products and processes. However, we are concerned here with the *use* of appropriation mechanisms. In order to determine this, we assume that the achieved level of effectiveness, *E*, of a particular appropriation strategy is determined by the impact (on prospective profits) for each dollar invested in the use of a mode, $E/\$$, and the amount of dollars expended, \$, i.e. $E = \$ \times E/\$$. Assuming that firms approximately equate the impact per dollar across each appropriation strategy, relative measures of the *effectiveness* of each appropriation strategy should also reflect the *use* of each appropriation strategy.

In addition to the knowledge management strategy, two other variables should be represented empirically: the value of a unit of retained knowledge, *v*, and the cost of increasing the stock of knowledge through each knowledge management strategy, *c*. We assume that *v* varies directly with how important innovation is to the firm's competitive strategy. The costs of knowledge management strategies are represented by the firm's industry; its technology area; and the market conditions it faces, the extent to which the firm employs differing methods of internal communication between employees; how extensive networks are within the firm's industry; and the mean level of R&D within the firm's industry. We expect that the extent of intra-firm communication will affect firm's absorptive capacity while the extent of industry networking and R&D will indicate the prevalence of external knowledge.

In our model, the firm's competitive strategy is the mean of 6 Likert-scale questions from the survey about how important product innovation is for the firm and 3 questions on how important process innovation is. Industry is accounted for by a series of 6 mutually exclusive industry dummies (*Mining*, *Manufacturing*, *Utilities*, *Trade*, *Finance*, and *Government*). For firms with a patent stock, we also included 3 dummy variables relating

to the technological areas[8] in which the firm holds a patent (*Instruments, Chemical* and *Mechanical engineering*). The Likert-scale variables from the survey were employed to provide 4 measures of market conditions in which the firm operates. These consisted of: how quickly marketing practices are changing; the rate of product obsolescence in the market; how predictable competitor's behaviour was; how unpredictable customers are; how often the production technology changes and how easy it is for firms to enter and exit the industry (*Changing marketing, High obsolescence, Competitors unpredictable, Demand unpredictable*).

For the costs of learning, the level of intra-firm communication was the average of two questions on the number of procedures used to communicate to employees and how well the strategic mission was understood within the firm. The average level of networking in the firm's industry was the average from the survey how often all surveyed firms reported they were involved in formal and informal networking; and the average level of R&D in each industry was the average annual expenditure on R&D by firms. Descriptive information on the exact questions are provided in Table A1.

5. Estimation Results

We estimated Equations 5-8 (Models 1-4)[9] using the seemingly-unrelated-regression (SUR) method to account for possible respondent biases across questions for the same respondent. In each system of equations, the Breusch-Pagan test rejected the hypothesis of zero correlation between the error terms across the equations. Since we are using a profit-maximising framework, we excluded not-for-profit organisations, leaving us with just over 600 complete survey responses. We treated each observation as independent and estimated each model as a pooled cross-section.[10] Results from estimating the four models –

[8] We use the Office of Science and Technology (OST) classifications from the major International Patent Classification code.

[9] In these 4 models, we empirically investigate the relationship between 2 appropriation mechanisms (patents, secrecy) and 2 learning styles (open, closed). The empirical model could be expanded to include additional types of learning and appropriation.

[10] There are some repeat firms in the cross-section. That there are 943 firm-year observations from 724 independent firms.

representing progressively lower degrees of aggregation – are presented in Table A2 and Table A3. The results from Model 1 reveal that when we estimate the extent of use of appropriation and learning as two single combine strategies, they are complementary. Product innovators appear to value each appropriation Likert point more than non-product innovators, while process innovators appear to value each learning Likert point more than non-process innovators. In addition, firms which have more developed internal communication systems and those operating in industries with more reported networking and more industry R&D appear to place a higher value on each learning unit than others.

While it is not possible to directly interpret the coefficients on the learning and appropriation variables, from Equation 4 it can be seen that the ratio of the coefficients on the appropriation and learning variables in Models 2, 3 and 4 give us the ratios of the beta parameters from the respective knowledge equations. Model 2 produces estimates of the ratios of the three beta coefficients and these are presented in Table 4. Internal consistency requires that either $\beta_{Ao} < 0$ and $\beta_{Ac}, \beta_{oc} > 0$ or $\beta_{Ao} > 0$ and $\beta_{Ac}, \beta_{oc} < 0$. Since we expect that the two forms of learning have positive synergies (i.e. that $\beta_{oc} > 0$) then the estimates reveal that open learning sabotages appropriation but that closed forms of learning and appropriation are synergistic.

Table 4: Estimates of relative beta coefficients

Variables	*Coefficients*	*Estimate*
$\frac{Appropriation \,\&\, OpenLearning}{Appropriation \,\&\, ClosedLearning}$	$\frac{\beta_{Ao}}{\beta_{Ac}}$	-0.20
$\frac{Appropriation \,\&\, OpenLearning}{OpenLearning \,\&\, ClosedLearning}$	$\frac{\beta_{Ao}}{\beta_{oc}}$	-0.10
$\frac{Appropriation \,\&\, ClosedLearning}{OpenLearning \,\&\, ClosedLearning}$	$\frac{\beta_{Ac}}{\beta_{oc}}$	0.50

Source: Table A2

To examine the nature of the relationship between appropriation and learning further, Model 3 disaggregates the appropriation variable into patents and secrecy and examines the relationship with the single learning strategy. Table 5 presents the results from this

estimation. Since all estimated beta ratios are positive, the betas must be either all positive or all negative (which we consider highly unlikely). Assuming the betas are positive, this implies a positive synergistic relationship between each of the appropriation mechanisms (patents and secrecy) and the overall learning strategy. In addition, it supports the position that patents and secrecy are complementary appropriation strategies.

Table 5: Estimates of relative beta coefficients

Variables	*Coefficients*	*Estimate*
$\frac{Patents \ \& \ Learning}{Patents \ \& \ Secrecy}$	$\frac{\beta_{pL}}{\beta_{ps}}$	0.59
$\frac{Secercy \ \& \ Learning}{Patents \ \& \ Secrecy}$	$\frac{\beta_{sL}}{\beta_{ps}}$	0.49
$\frac{Patents \ \& \ Learning}{Secrecy \ \& \ Learning}$	$\frac{\beta_{pL}}{\beta_{sL}}$	1.22

Source: Table A3

Finally, Model 4 presents the 2×2 option, which gives us further information about the relationship between appropriation and learning strategies. In Table 6, the first four rows present the coefficients for both forms of appropriation with both types of learning in the numerator. These are all divided by the patents-by-secrecy coefficient. The second set of four rows presents the same four coefficients in the numerator but uses open learning-by-closed learning coefficient in the denominator. The revealed pattern of estimates is consistent with the preceding models. Given that β_{ps} is positive, the results suggest a negative relationship between patents and open learning (i.e. $\beta_{po} < 0$), but a very strong and positive relationship between patents and closed learning (i.e. $\beta_{pc} > 0$). The relationship between secrecy and open learning was very small and insignificantly different from zero. The relationship between secrecy and the closed-learning modes was positive and significant but only one third the size of the relationship between patents and closed-learning. Finally, a comparison of the first four rows with the last four shows that the size of the synergy between open and closed learning (β_{oc}) is greater than the synergy between

patents and secrecy (β_{ps}) since the coefficients in the last 4 rows are smaller than the first 4 rows.

Table 6: Estimates of relative beta coefficients

Variables	*Coefficients*	*Estimate*
$\frac{Patents \,\&\, OpenLearning}{Patents \,\&\, Secrecy}$	$\frac{\beta_{po}}{\beta_{ps}}$	-0.67
$\frac{Patents \,\&\, ClosedLearning}{Patents \,\&\, Secrecy}$	$\frac{\beta_{pc}}{\beta_{ps}}$	0.93
$\frac{Secrecy \,\&\, OpenLearning}{Patents \,\&\, Secrecy}$	$\frac{\beta_{so}}{\beta_{ps}}$	0.10[(a)]
$\frac{Secrecy \,\&\, ClosedLearning}{Patents \,\&\, Secrecy}$	$\frac{\beta_{sc}}{\beta_{ps}}$	0.25
$\frac{Patents \,\&\, OpenLearning}{OpenLearning \,\&\, ClosedLearning}$	$\frac{\beta_{po}}{\beta_{oc}}$	-0.20
$\frac{Patents \,\&\, ClosedLearning}{OpenLearning \,\&\, ClosedLearning}$	$\frac{\beta_{pc}}{\beta_{oc}}$	0.28
$\frac{Secrecy \,\&\, OpenLearning}{OpenLearning \,\&\, ClosedLearning}$	$\frac{\beta_{so}}{\beta_{oc}}$	0.03[(a)]
$\frac{Secrecy \,\&\, ClosedLearning}{OpenLearning \,\&\, ClosedLearning}$	$\frac{\beta_{sc}}{\beta_{oc}}$	0.08

Note: (a) not significantly different from zero.
Source: Table A3

Taken together, these results suggest that firms trade-off appropriation and learning strategies in order to manage their incoming and outgoing knowledge flows. The most important trade-off (i.e. negative relationship) is between patents and open learning: firms maximise incoming knowledge flows by adopting an "open" stance, but this directly affects their ability to use patents as a means of appropriating innovation profits. At the same time, there is a strong positive relationship between patents and closed learning: firms which follow the patenting path, for either technological or strategic reasons, are positively

affected by learning through patent disclosures, publications and technical meetings and R&D etc. However, they also tend to curb their learning from formal and informal networking and exchanging freely with customers and suppliers. Firms that chose the secrecy route, *ceteris paribus*, obtain no synergies from open forms of learning and only small synergies from closed forms of learning. Nonetheless, all firms obtain positive synergies from combining both open and closed forms of learning. These appear to be stronger that the synergies from combining patents with secrecy.

6. Conclusions

This paper aims to contribute towards the discovery of systematic factors explaining how firms manage knowledge flows by examining trade-offs and synergies between appropriation and learning strategies. In particular, we examine the relationships between patents/secrecy and open/closed learning. In a world where firms increasingly rely on intellectual capital and assets which are not easily traded, firms' learning strategies appear to be an important means for firms to gather, develop and create new knowledge. However, they must also try and keep some of the knowledge private in order appropriate the returns from the knowledge created. This suggests the existence of a fundamental paradox – which has recently been referred to as the "paradox of openness" – in firms' learning and appropriation strategies. In this paper, we found evidence that open learning styles do undermine appropriation strategies. Specifically, we found that open learning undermines the effectiveness of patents as appropriation mechanisms.

Table A1: Variable definitions and descriptive statistics

VARIABLE	*DESCRIPTION*	*MEAN*	*STANDARD DEVIATION*
Extent of Learning			
All types	An 11-item, 7 point scale measuring the extent to which the organisation learns about new products and processes from open and closed sources.	3.658	1.100
Open learning	A 5-item, 7 point scale measuring the extent to which the organisation learns about new products and processes from informal and formal networks, hiring skilled employees, lead customers and suppliers.	4.294	1.207
Closed learning	A 5-item, 7 point scale measuring the extent to which the organisation learns about new products and processes from licensing technologies, patent disclosures, publications and technical meetings, reverse engineering, R&D and consultants.	3.375	1.166
Extent of Appropriation			
All types	A 16-item, 7 point scale measuring how effective patents, secrecy, lead-time, know-how and brands are protecting the competitive advantage from new products and processes	3.672	1.615
Patents	A 2-item, 7 point scale measuring how effective patents are protecting the competitive advantage from new products and processes	2.841	2.022
Secrecy	A 2-item, 7 point scale measuring how effective secrecy is protecting the competitive advantage from new products and processes	3.295	1.935
Innovative Strategy			
New products	A 6-item, 9 point scale measuring the emphasis on creativity and innovation, state-of-the-art products as a form of competition	0.082	0.959
New processes	A 3-item, 7 point scale measuring the emphasis on operational efficiency and increasing productivity as a form of competition.	0.116	0.792
Internal communication	A 2-item, 7 point scale measuring the extensiveness of intra-firm communications.	-0.044	0.814
Industry networks	A 2-item, 7 point scale measuring the extent to which firms in each major industry engage in formal and informal networking.	4.594	0.315
Industry R&D	Firm-average R&D expenditure by major industry.	4878	3921
Market Conditions			
Dynamic marketing	A single-item, 7 point scale measuring how rapidly the firm changes its marketing practices.	4.577	1.301
High obsolescence	A single-item, 7 point scale measuring the rate of obsolescence in the firm's product markets.	3.461	1.671
Competitors unpredictable	A single-item, 7 point scale measuring how unpredictable firms' competitors are.	3.617	1.350
Demand unpredictable	A single-item, 7 point scale measuring how rapidly the firm's production/service technology changes.	3.853	1.471

Source: Melbourne Institute Business Survey 2001-2004

Table A2: Determinants of Appropriation and Learning Strategies

	Model 1				*Model 2*					
	APPROPRIATION		LEARNING		APPROPRIATION		LEARNING			
	All types		All types		All types		Open		Closed	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Extent of learning										
All types	0.88**	16.23								
Open learning					-0.16**	-2.82			0.66**	22.46
Closed learning					0.82**	13.83	0.80**	22.40		
Extent of appropriation										
All types			0.41**	17.60			-0.08**	-2.97	0.33**	14.65
Patents										
Secrecy										
Innovative strategy										
New products	0.19**	3.24	-0.06	-1.63	0.15**	2.58	-0.06	-1.33	0.01	0.27
New processes	-0.02	-0.26	0.14**	3.02	0.00	0.02	-0.04	-0.74	0.10*	2.12
Internal communication			0.15**	3.46			0.08	1.54	0.01	0.29
Industry networks			0.53**	4.52			0.16	1.28	0.19†	1.73
Industry R&D			0.02†	1.77			-.03**	-3.08	0.03*	3.17
Market Conditions										
Dynamic marketing	0.00	0.07	0.05	1.72	0.04	0.90	0.03	0.99	-0.01	-0.33
High obsolescence	0.04	1.10	0.03	1.31	0.07†	1.84	0.00	0.16	-0.01	-0.32
Competitors unpredictable	-0.03	-0.71	-0.01	-0.38	-0.07	-1.49	-0.04	-1.17	0.04	1.38
Demand unpredictable	0.00	-0.01	0.00	-0.01	0.01	0.31	0.05†	1.68	-0.04	-1.42
Constant	0.13	0.43	-0.62	-1.06	1.16**	3.55	1.10†	1.72	-1.65**	-2.94
Industry dummies	Yes		No		Yes		No			
Technology dummies	Yes		No		Yes		No			
Estimation method	SUR		SUR		SUR		SUR		SUR	
Breusch-Pagan test of independence	chi2(1) =72.397, Pr = 0.0000				chi2(3) = 192.338,Pr = 0.0000					
Sample size	667		667		613		613		613	

Note: ** significant at the 1% level, * significant at the 5% level, † significant at the 10% level..

Table A3: Determinants of Appropriation and Learning Strategies

	Model 3						*Model 4*							
	APPROPRIATION				LEARNING		APPROPRIATION				LEARNING			
	Patents		Secrecy		All types		Patents		Secrecy		Open		Closed	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Extent of learning														
All types	0.44**	6.47	0.35**	5.22										
Open learning							-0.49**	-7.41	0.07	1.07			0.70**	24.8
Closed learning							0.68**	9.42	0.18*	2.43	0.88**	24.72		
Extent of appropriation														
All types														
Patents			0.72**	22.86	0.15**	6.96			0.72**	22.54	-0.17**	-7.33	0.19**	9.65
Secrecy	0.74**	22.83			0.12**	5.52	0.73**	22.53			0.02	0.98	0.05	2.58
Innovative strategy														
New products	0.09	1.35	0.00	0.06	-0.04	-0.96	0.05	0.79	0.00	-0.01	-0.03	-0.81	0.02	0.54
New processes	-0.02	-0.23	-0.14†	-1.71	0.20**	4.24	0.00	-0.03	-0.12	-1.46	-0.05	-0.96	0.13**	2.85
Internal communication					0.17**	3.91					0.05	1.11	0.02	0.60
Industry networks					0.43**	3.70					0.14	1.11	0.10	0.93
Industry R&D					0.01	1.61					-0.02	-2.50	0.02**	2.70
Market Conditions														
Dynamic marketing	0.11*	2.04	-0.13**	-2.57	0.06†	1.88	0.14**	2.78	-0.12*	-2.32	0.05	1.56	-0.02	-0.73
High obsolescence	-0.01	-0.29	0.02	0.50	0.04†	1.66	0.00	0.02	0.04	0.88	0.01	0.38	0.00	-0.19
Competitors unpredictable	-0.01	-0.23	0.01	0.20	-0.02	-0.69	-0.04	-0.84	0.00	0.00	-0.04	-1.39	0.04	1.32
Demand unpredictable	-0.07	-1.38	0.07	1.40	0.00	-0.04	-0.04	-0.88	0.06	1.36	0.04	1.46	-0.03	-1.35
Constant	-1.51**	-4.18	0.20	0.57	0.48	0.83	-0.17	-0.46	0.48	1.27	1.00	1.62	-0.84	-1.56
Industry dummies	Yes		Yes		No		Yes		Yes		No		No	
Technology dummies	Yes		Yes		No		Yes		Yes		No		No	
Estimation method	SUR		SUR						SUR		SUR		SUR	
Breusch-Pagan test of independence	chi2(3) = 177.385, Pr = 0.0000						chi2(6) = 337.013, Pr = 0.0000							
Sample size	613		613		613		616		616		616		616	

Note: ** significant at the 1% level, * significant at the 5% level, † significant at the 10% level..

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