PATTERNS OF KNOWLEDGE FLOWS AND MNE INNOVATIVE PERFORMANCE

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ABSTRACT

This paper explores the influence of knowledge flows both within the MNE and from external organisations on MNE innovative performance. The paper's theoretical base relates to the notion of the 'differentiated' MNE. A key premise is that MNEs are characterised by a significant of organisational variation. The distinctiveness of subunits is partly a function of their in external business, technology and other networks suggesting that knowledge flows from external partners is beneficial to MNE innovativeness both directly through their impact of subunits and indirectly through stimulating knowledge flows from the subunits to other units within the MNE. Three hypotheses relating knowledge flows to MNE innovative performance is derived from the extant literature reviewed in the paper.

The paper uses patent citation and co-patenting data to track cross-border knowledge flows for a sample of 20 MNEs in the 'Biopharmaceutical' sector. A multivariate statistical approach utilising multiple regression analysis is used to establish the relationship between knowledge flow variables and innovative performance. . The results confirm that diverse knowledge flows are very beneficial for MNE innovative performance, especially from local/national organisations in the subunits immediate environment, supporting the importance of 'embeddeness' of MNE units.

INTRODUCTION

This paper investigates the influence of knowledge flows across national and organisational borders on innovative performance for multinational enterprises (MNEs) in the Biopharmaceutical Industry. Previous studies have examined the phenomenon of increasing internationally dispersed knowledge sources within MNEs, and have noted its effect on enhancing MNE capabilities and innovation (Cantwell, 1995; Pearce, 1999; Florida, 1997; Gupta & Govindarajan, 2000). However, the evidence for the impact of knowledge flows on MNE innovative capabilities is limited (Ghoshal and Bartlett, 1988; Papanastassiou and Pearce, 1999; Andersson and Forsgren, 2000; Subramaniam and Venkatraman, 2001). There is also much recent research emphasising inter-organisational networks for knowledge and learning, with knowledge channels from external institutions, often in the local or national environment, being important for innovation (De Meyer, 1993; Almeida and Kogut, 1999;Henderson, et al 1998). The amount, directions and dimensions of knowledge flows occurring across both national and organisational borders are therefore likely to have important implications for MNE-level innovative performance in this industry.

The aim of this paper is therefore to address these issues, considering knowledge flows as independent variables influencing innovation, primarily looking to answer questions concerning the knowledge flows, both within the MNE and with external institutions, which are most conducive to enhanced innovative performance. To answer these research questions, the paper reviews the key issues from the extant literatures on inter- and intra-organisational cross-border knowledge flows and generates hypotheses relating these knowledge flows to innovative performance in MNEs. The paper employs patent data to track cross-border knowledge flows, across national borders within MNEs and across organisational borders from other firms, universities and research institutions.

The most important finding from this analysis is that internal and external knowledge flows have a complementary and reinforcing positive impact on innovative performance and that this is particularly the case for knowledge of a more tacit character. A related finding is that external knowledge flows (from academia and from local or national organisations) to the MNE are a key influence on innovative performance, supporting previous studies emphasising the importance of local 'embeddedness' of MNE units (e.g. Andersson and Forsgren, 2000). Our analysis also provides initial support for the view that benefits can be accrued from cross-border or 'transnational' knowledge creation, identified by others as representing the mechanism for integrating the differentiated competencies of the MNE (Subramaniam & Venkatraman, 2001), for example through a 'global innovation' strategy (Pearce, 1999).

The remainder of the paper is structured as follows. Section I presents a review of the literature, focusing on the organisational context of the 'differentiated' MNE. Existing literature suggests that the organisational differentiation within the MNE is likely to encourage a level and pattern of knowledge flows, which help to promote innovative performance by reinforcing the interdependencies between internally and externally sourced capabilities. Thus a number of hypotheses are suggested relating intra and inter–organisational knowledge flows across MNE units and external organisations to the innovative performance of the MNE as a whole. Section II describes the empirical context of the study and the database construction. Section III presents the empirical analysis and discusses the findings. Section IV concludes the paper by considering implications of the findings, particularly for management practice.

I-DIFFERENTIATED MNES, INTRA AND INTER ORGANISATIONAL KNOWLEDGE FLOWS AND INNOVATIVE PERFORMANCE.

I.1 Background

There is now a considerable weight of evidence to support the increasingly significant innovative role of MNEs, due to increased decentralisation of innovative activity (Cantwell, 1995). The extent of this phenomenon is evidenced by MNEs in all industry sectors allocating an increasing proportion of their R&D abroad (Cantwell, 1995;Florida, 1997), although this is mostly limited to the triad countries therefore showing more of a regionalisation pattern (Archibugi & Michie, 1995). Nevertheless, innovation is increasingly global in nature, the US especially attracting a large amount of foreign R&D pending (Florida, 1997). Such an increase in decentralised R&D indicates the increasing importance of MNEs in the exploitation of market and technological heterogeneity worldwide for knowledge creation, moving away from the traditional home-centred approach to innovation.

The significance of MNEs in the internationalisation of innovative activity has led to a large stream of literature regarding the behaviour of subsidiaries that have acquired a competence-creating role. This includes considerations of 'creative subsidiaries' as 'centres of excellence' (Pearce, 1999; Andersson & Forsgren, 2000; Frost et al, 2002) with a role to generate independent technological capabilities in accordance with the local innovative environment (Papanastassiou & Pearce, 1999; cant well & Janne, 1999; Pearce, 1999; Zander, 1999; Frost, 2001). The focus of this literature is a movement away from traditional subsidiary roles of adopting current MNE technology developed in the parent company, to the creation and development of local technological competencies complementary to the rest of the MNE which could involve diffusion of such innovations to elsewhere in the MNE (Ghoshal & Bartlett, 1988). There is indeed much evidence to suggest that the MNE is likely to develop into a differentiated organisation, whereby subsidiaries possess such a distinct set of capabilities that reflect the unique combination of market, technological and institutional features. The subsidiary's network of external linkages with suppliers, competitors and research institutions represents a significant stimulator of innovation, enhancing the differentiation of subsidiaries from the parent company (Pearce and Papanastassiou, 1999; Forsgren et al, 1999).

A crucial question is how these differentiated competencies are integrated at the firm level, introducing the inherent contradiction between subsidiary autonomy and MNE-wide integration. Thus the organisational design problem of the differentiated MNE has been stated by Foss & Pederson (2002) to include both the need for subsidiaries to produce knowledge by tapping into local knowledge bases, and for such knowledge to be made available to other MNE units. However, although any form of cross-border knowledge creation will be founded on a level of knowledge flows; such flows are not necessarily a wholly unmixed blessing – at least from the perspective of innovation and knowledge creation. In particular, if cross-border knowledge flows become a frequent and thus a routine feature of intra-organisational interactions in the MNE, their innovative productivity may be dulled. Furthermore there is a possibility that knowledge flows may in effect become an instrument for organisational control rather than for innovation, particularly as the direction of knowledge flows may primarily be from the parent to the subsidiaries. These possibilities are less likely in an inter-organisational compared to an intra-organisational context. Recent research indicating that inter-firm cooperation and alliances tend to be more effective compared to direct foreign investment in broadening the geographical scope of MNE capabilities (see e.g. Dunning and Lundun, 1998) tend to lend support to this expectation.

In fact, the very notion of the 'differentiated' MNE suggests that intra- MNE flows of tacit knowledge tend to be rather limited and far from a routine feature of the organisation (von Hipple, 1994; Szulanski 1996; Kostova 1999; Zander and Sölvell, 2000; Gupta and Govindarajan 2000). A low level of intra-MNE knowledge transfers is a necessary condition for the maintenance of differentiation and diversity within the MNE. If it were the case that knowledge transfers across national boundaries were totally smooth and 'un-sticky', the organisational differentiation that is characteristic of the MNE would itself be gradually eroded. However, low levels of knowledge transfer should not necessarily be interpreted as implying an absence of opportunity or incentive for cross border knowledge sharing or innovation. In terms of Hansen's analysis of knowledge sharing across organisational subunits, a differentiated MNE is a 'weakly-coupled' organisation with the advantage of offering greater 'search' opportunities for identifying novel ideas, concepts and practices useful in product development and innovative activities of the searching subunit (Hansen, 1999). This suggests that the admittedly low levels of knowledge transfers that do take place are likely to be potentially highly productive as there is significant scope for cross-unit learning. In a tightly coupled organisation, in which cross-unit contacts and knowledge flows are both frequent and intensive, subunits have full knowledge of each other's capabilities, and the chances of finding useful novelty is absent or low (see also Ahuja, 2000; Ref, 2002). The recent research on 'reverse' transfer within MNEs (Birkinshaw et al 1998; Yamin, 1999; Pearce 1999; Hakanson and Nobel, 2001) illustrates that local embeddedness of subsidiaries in external networks and a degree of integration with the rest of the MNE are not incompatible phenomena (Buckley and carter 2002). There is also recent evidence of cross unit collaboration to impart a degree of 'transnationality' to new products developed mainly by the parent unit (Subramaniam and Venkatraman, 2001)[1].

I.2 External knowledge flows and innovative performance

Although internal knowledge flows are considered as the mechanisms for MNE-wide innovative outcomes, such knowledge flows are only likely to be beneficial *if* individual subsidiaries are able to develop their distinctive capabilities in a sustained manner. The logic underlying the notion of the ' differentiated' MNE strongly implies that subsidiary capabilities are developed in a context of embeddedness in networks of relationships and in particular in network of relationships with external partners. An expanding stream of recent literature attests to the important role that external linkages play in the development of subsidiary capabilities (e.g. Andersson and Pahlberg 1997; Holm and Fratocchi1998; Birkinshaw and Ridderstrale, 1999; Forsgren et al 1999; Andersson and Forsgren, 2000). These linkages are beneficial, in turn, because they facilitate knowledge flows from various exchange partners in the local business and other networks to the MNE subsidiary. These external knowledge flows are therefore expected to enhance the innovative performance of MNEs both through their direct effect on innovation by the subsidiary and indirectly through stimulating knowledge flows between the subsidiaries and other units within the MNE.

An important feature of external linkages is probably their heterogeneity and may include both business linkages and linkages with non-business institutions such as universities and other research establishments. This distinction is particularly important in cases where the MNE is motivated to tap into the science base of the host country–a key consideration in the life science and biotechnology sectors amongst others. Regarding knowledge flows from universities, research institutions and government research laboratories, there is evidence in the literature that knowledge flows from these sources will enhance innovation of the internalising firm (Cockburn and Henderson; 1998). This is especially relevant for biopharmaceutical industry as technological change and innovation is more closely tied to advances in basic science. The importance of collaborative research ties to the academic community for a firm's productivity has also been shown (Cockburn and Henderson; 1998) suggesting more complex interactions than a simple linear model of innovation. It is apparent from the literature that research in public laboratories (government, research institutions) is akin to that of university research rather than private firm research (Henderson, et al, 1998), therefore in this study we will bracket all research institutions **as**

[1] Of course as Hansen (1999) points out knowledge sharing /creation across organisational subunits will require a high degree of coupling and interaction. However this can be provided through the creation of temporary teams that come together for the specific purpose of new product development (see also Hedlund and Ridderstrale 1995; Subramaniam et al, 1998)

'academia' for ease of interpretation. There is evidence in the literature for such industry-academia knowledge flows and knowledge sharing relationships influencing the innovation of all firm types in the industry. We therefore hypothesise that knowledge flows both from other firms and from research and academic institutions will have a positive influence on innovative performance:

H1: External knowledge flows will have a positive influence on the MNE's innovative performance.

I.3 Internal knowledge flows and innovative performance

We hypothesise a generally positive effect from intra MNE knowledge flows on innovative performance. The reason underlying this expectation derives from specific organisational features of the 'differentiated' MNE. Thus, as previously noted, the organisational and geographical separation between subsidiaries and the parent on the one hand and relatively higher degrees of embeddedness in external as compared to internal networks militates against very high levels of cross border knowledge flows, which we have argued will be detrimental to subsidiary innovativeness and would hence reduce the opportunities for cross border knowledge development. The more common pattern of intra- MNE knowledge flows is dyadic and takes place in a vertical relationship between the parent and an individual subsidiary. The 'reverse' transfer of innovation from subsidiaries to the parent is clearly an example of dyadic and vertical knowledge flows (Hakanson and Noble, 2001). The empirical study of 'transnational' product development by Subramaniam and Venkatrman (2001) also portrays an essentially vertical pattern of knowledge flow from a number of subsidiaries to the parent with little indication of lateral knowledge flows. However with rapid technological change, product development and innovation requires a broad range of competencies (Ahuja, 2000). On the other hand, due to the persistence of market and demand heterogeneity 'global for local' strategies increasingly have to give way to genuine transnational strategies (Pearce and Papanastassiou 1999; Subramaniam and Venkatraman, 2001). These parallel considerations imply that in the future there may be a greater net payoff from patterns of knowledge flow that incorporate both vertical and lateral directions and utilise more fully the technological and capability differentiation within the MNE even allowing for the greater cost of coordination that is probably entailed. Taking account of the above of the above and bearing in mind the underlying barriers to excessive knowledge flow within the MNE we hypothesise:

H2: Cross border intra-MNE knowledge flows will have a positive influence on the firm's innovative performance.

I.4 Knowledge flow diversity and innovative performance

The previous discussions of the importance of exploiting external knowledge sources, and also of the MNE as a differentiated organization with dispersed, heterogeneous capabilities, are linked to the notion of knowledge diversity. In uncertain, knowledge based environments, a diverse background provides a stronger knowledge base and therefore a more robust basis for learning. This draws on the notion of invention and technological creation as a process of recombinant search (Basalla, 1988), with diversity stimulating innovation through increasing the potential and speed of novel associations and linkages (Cohen & Levinthal, 1990; Ruef, 2002). R&D intensive firms especially require a wide range of specialised skills and knowledge, often stretching beyond the firm's own in-house capabilities, and perhaps beyond that of the national R&D infrastructure (Tijssen, 2001). An excessive focus on purely internal activities through learning by doing will therefore reduce diversity, suggesting that firms should expand their knowledge base by combining various sources of both domestic and international external knowledge.

Critics of diversity emphasise the complications of managing too much heterogeneous information while stressing the advantages for innovation accrued from specialisation (Dougherty, 1992). This line of thought views innovation as incremental and holds that firms need extensive deep learning in order to be highly innovative, which will necessarily correlate with less diversity (Cohen and Levinthal, 1990). There is clearly some theoretical ambiguity with regard to the net effect of knowledge diversity on innovative performance. However in the specific context of the MNE, as we have already noted, the level of knowledge flows tend to be on the low side thus reducing to an extent problems associated with coordination and absorptive capacity emanating from diversity. The overall effect of knowledge diversity in this context may therefore be expected to be positive.

H3: Diversity in knowledge flows has a positive effect on MNE innovative performance

I.5 -Other factors influencing innovative performance

There are, of course, other factors aside from knowledge flow issues that may be significant in determining the innovative performance of MNEs in the Biopharmaceutical industry; these are controlled for wherever possible in the analysis. Before presenting the model incorporating all explanatory variables as identified in the hypotheses above, it is therefore first necessary to identify these other influencing factors.

I.5. 1 *Size of firm*

There is a substantial body of evidence suggesting scale economies in the innovation and patent production function. There is also evidence of a positive relationship between a firm's size and its ability to capture value from R&D investments (Cohen and Levin, 1989). Other research has suggested that organisational size is associated with an increased availability and access to critical resources, which may enhance performance (Gooding & Wagner, 1985). Contrary to this is the emphasis on the importance of small firms' contribution to innovation in high technology industries the biotechnology industry being one that has received increasing attention (Austin, 1993). It has been shown elsewhere with the use of patent and R&D expenditure statistics that small firms appear to be more 'efficient', receiving a larger number of patents per R&D dollar (Grilliches, 1990). The organisational size-performance relationship therefore has inconclusive findings. The potential relationship should nevertheless be considered, and size included is as a control variable in the study.

I.5.2 *Age of firm*

Organisational age may also be linked with innovative performance and so should also be included as a control variable in the study. Older organisations could have an advantage over newer firms due to increased information and resources, more acquired experience and expertise, more patents and products in the pipeline, established external relationships, further developed R&D activities and increased learning curve effects. However, our measurement of performance is of 'innovative performance', focusing purely on patents and R&D expenditure and not considering financial factors or existing products, so should not incur all of these problems. Nevertheless, age should still be included as an important control variable. Furthermore, there is evidence, although uncertain, in support of the negative effects of aging on innovation (Barnett, 1990), to include the displacement of established firms by new start-up companies This evidence includes recent studies that have demonstrated relationships between patenting rates and organisational age, therefore relevant to this study. These have shown both positive and negative effects to be associated, the outcome reflecting trade-offs in the learning and innovation process (Sorenson and Stuart, 2000). The positive consequences are justified by increased experience enabling cumulative improvements which enhance innovation; the negative consequences are associated with problems in keeping abreast of the most recent external technological advances and the resulting decrease in relevance of innovative capabilities (Sorenson and Stuart, 2000). This seems especially applicable to the industry under study, as the established pharmaceutical firms tend to produce incremental innovations along existing technological trajectories and may therefore encounter difficulties in incorporating the radical biotechnology developments. The radical innovations themselves are emerging from the new biotechnology firms.

I.5.3 *Nationality of firm*

It is evident from the earlier discussion that country-specific institutional configurations are significant in shaping distinct national patterns of innovation, which will likely influence the properties of national firms (Jaffe & Trajtenberg, 1999). It is therefore necessary control for the nationality of the firms in the model. Due to the strong institutional differences existing primarily between European biotechnology and that of the US, with a resulting impact on inter-organisational knowledge flows and successful innovation, I will distinguish between whether a firm is European or US, as this should incorporate any major influential country-specific factors.

II- EMPIRICAL CONTEXT AND DATA SET

II .1 Industry focus and company sample

The Biopharmaceutical industry was chosen as the framework for study for two reasons. Firstly, there are distinct and easily characterised innovating firms present in the industry. Using this industry as the empirical setting therefore provides a unique opportunity to study, on the one hand, biotechnology MNEs which have emerged very recently, and on the other hand, established pharmaceutical MNEs which have been around for many decades; both groups being exposed to a similar competitive, knowledge intensive environment and the same technological trends. Second, the testing of the issues relating to knowledge flows and innovation in the context of the Biopharmaceutical industry is especially important, due to the knowledge intensive nature of the industry with intellectual capital a major driver of growth. The crucial role of knowledge as a determinant of success in the biotechnology-based industries is evident, due to the very high degree of science intensity of biotechnology (Saviotti, 1998). There is therefore a particularly important emphasis on learning, knowledge creation and increased knowledge flows as factors likely to significantly affect a firm's capabilities. The parallel with the need for MNEs to achieve a balance between external and internal knowledge flows, as highlighted in the notion of the 'differentiated MNE' is clear. This is further emphasised by studies recognising the importance of organisational learning and innovation as located in networks (Powell et al, 1996). This discussion serves to highlight further the proposition that a diverse body of knowledge from a range of sources, to include knowledge flows between both units of individual firms and external organisations, is likely to be required for learning and innovation in complex and rapidly advancing areas.

The sample of firms in this study consists of pharmaceutical MNEs and those biotechnology MNEs with research focus on pharmaceutical applications. We have recorded patents granted to 20 such MNEs. 'Biopharmaceuticals' includes the large incumbent pharmaceutical MNEs and the dedicated biotechnology firms, new since the emergence of the biotechnology phenomenon, which can be further divided into the recently established biotechnology MNEs and the small biotechnology uni-national firms. We focussed only on the MNE sub-sample and excluded all non-MNEs. We included the two categories of MNEs (i.e. pharmaceuticals and biotechnology MNEs), as they are likely to vary in their knowledge flow types.

Considering the pharmaceutical MNE sample, those with a large amount of consumer products in their portfolio were avoided, choosing companies instead who were fairly focused on the pharmaceutical operations. We therefore did not include in the sample any companies whose pharmaceutical sales were less than one-third of their total sales. Considering the biotechnology firm sample, we used the population of Biotechnology MNEs with applications in the area of pharmaceuticals to draw the company sample. The Dow Jones List from the database Osiris was used as a starting point for choosing the biotechnology firm sample, using the global index classification 'BTC' to give a comprehensive list of biotechnology firms in operation. From this, MNEs with applications in pharmaceuticals and human healthcare were identified.

II.2 Variable definition and measurement

II.2.1 *Dependent Variable: Innovative Performance*

There is no general agreement on the best method of measuring the output of innovation. However, the use of patents is suitable to this study, as it has been shown to be a function of R&D effort in the industry under study. The measurement used for innovative performance is *the number of patents per expenditure on R&D* (in billion US dollars), as calculated in the given time frame of a 5-year period. The rationale for this measurement is that it is vital to control for firm-specific R&D expenditure, as the larger firms in the sample will obviously produce more patents, but this does not mean they are necessarily more innovative relatively compared to the smaller ones. It has been rigorously demonstrated that it is the previous years' R&D investment that has the most influence upon patenting (Hall et al, 1986), therefore we employ R&D expenditures for years 1997-2001, and the patent counts for years 1998-2002 in our calculation of the dependent variable.

II.2.2 *Independent variables: knowledge flows*

Knowledge flows encompass both 'informal knowledge flows' and 'collaborative knowledge sharing':

'Informal knowledge flows' are defined as the transfer of previously existing knowledge from one inventor to another for use in the creation of new knowledge. Informal knowledge flows thus correspond to 'spillovers' and are measured at firm level through patent citations. When a patent is filed, all 'prior art' relied upon by the inventor is listed as citations, providing an indication of previous knowledge used to create the new knowledge embodied in a patent. A citation of patent X by patent Y implies therefore that X represents a piece of previously existing knowledge upon which Y builds. The validity of drawing inferences from citation data about knowledge spillovers is addressed fully in Jaffe et al (1993). Knowledge spillovers can be seen to leave a 'paper trail' in the form of such citations. The present study of cross-border knowledge flows is facilitated by this paper trail, providing a way to trace the knowledge utilised by an

inventor of a certain patent. This information can therefore be used to trace the transfer of knowledge across inventors, institutions, and geographic locations. In the empirical analysis we distinguish between three types of informal knowledge flows, each measured by the *mean number of citations per patent***.** We distinguish between mean number of 'academic' patent citations per patent ('academic' patents include patents awarded to universities, other research bodies and government organisations) and the mean number of citations to other firm's patents per patent (see also table 1 below).

'Collaborative knowledge sharing' is defined as the knowledge flows or knowledge exchange occurring when inventors from different institutions, or different units within the same firm, engage in joint research. This is measured by the 'co-authorship' of patents (as indicated by 'co-assignees'). Co-patenting involves a qualitatively different kind of interaction compared to that of the citation patterns (Cockburn & Henderson 1998). This is due to co-authorship reflecting joint research, which requires real investment on the part of the firm, and is likely to represent socialisation and tacit knowledge exchange, whereas citation patterns may only represent codified knowledge flows that occur impersonally and do not necessarily imply face-to-face interaction. For collaborations with each type of institution, the measurement used was **%** *patents collaborated* for the 5-year period. (See table 1) These collaborated patents were identified by the 'co-authorship' of patents for external collaborations, indicated by more than one institution on the 'assignee' name of the patent, or for internal collaborations between different subsidiaries as indicated by inventors in more than one country.

II.2.3 *Independent variables: diversity measures*

The range of citations in any given patent is here assumed to reflect the diversity of knowledge flows resulting in creation of the new knowledge contained within the patent. Knowledge flow diversity is computed for each patent, and then the means calculated for each firm as follows. For patent i the number of citations of type j is denoted as $n_{i,j}$ and the total number of citations aggregated over all types (j = 1…J; $J = 20$[2]) as n_j. The proportion of patent i's citations of type j, out of the total number of ties, is denoted $p_{i,j}$ and given by $p_{i,j} = n_{i,j}/n_j$. Each $p_{i,j}$ is squared and then the sum taken over all j and then subtracted from 1, resulting in the index of diversity, y_j, so that:

$$y_j = 1 - \sum_{j=1}^{J} (P)_{ij}^{2}$$

[2] Diversity is treated as a continuous random independent variable, in the range of 0 to 20 (this is the total number of citation sources defined for this study). The geographical location of citations is in four categories: local, regional, national and global. For each location category there are five types of flows/ citations: internal, external company, university, research institution and other.

This is derived from Blau's index of heterogeneity (Blau, 1977), and has been utilised by others, including Powell et al (1996), in a study of the diversity of collaborative ties of biotechnology firms.). This index was also used for representing the diversity of patent locations of the firms under study to indicate the approximate extent of internationalisation of R&D of the specific firms. It was also used to represent the diversity of collaborative ties as indicated by co-patenting, and the diversity of knowledge flows to include external only types, or to include only location. These calculations will be the same as that above, with a smaller total J number.

II.2.4 *Control variables*:

Size is operationalised as the logarithmic transformation of the number of full time employees, to account for decreasing returns to scale in keeping with conventions. Age is operationalised as the number of years from founding for each firm. Country differences are controlled for by use of a dummy variable, to distinguish between European firms and US.

Insert Table 1 here

III –DATA ANALYSIS AND DISCUSSION OF FINDINGS

III.1 Regression analysis

A multivariate analytical approach utilising, multiple regression was the statistical procedure used to establish relationships between the variables and test the hypotheses. Means for each variable for the period from 1997-2002 were calculated for entering into the following regression model:

Y= f (C; I;EKT; IKT; DKF)

Where,

Y= innovative performance of the firm

C= control variables (age, size, country)

I = industry controls for the type of innovating firm

EKT = knowledge flows across organisational borders from external institutions

IKT = Knowledge flows within the MNE

DKF= Diversity in knowledge flows

As already indicated knowledge flows are represented both by 'informal flows' (capturing potential. spillovers) and by knowledge sharing across external and internal organisational boundaries. Both types of knowledge flows are separately recorded for different types institutions (i.e. academic and commercial organisation). Table 1 shows the list of variables employed in the regression analysis and indicates what data is used to operationalise each variable. Table 2 shows the correlation matrix of the variables. The correlation matrix reveals a very high correlation between the variables labelled DIV TYPES and ACAD and also between DIV ALL and EXT FIRM (see below)

Table 2 here

Table 3 shows the results of nine selected multiple regression equations, exploring the influence of the knowledge flow types, both across organisational borders (i.e. from other firms and institutions) and across national borders within the MNE. The standardised coefficients are shown in parenthesis for ease of comparison of the impact of the different variables within each equation. Equation 1 includes the control variables of size, nationality and age. The equation is significant at the $p<0.05$. Size is the most significant variable in this equation, showing a negative effect on innovative performance. Nationality is also slightly significant, with a positive coefficient therefore indicating that the US firms in the sample are slightly more innovative than the European firms. The addition of industry dummy (in equation 2) increases in adjusted R^2, to 42% of the variation in innovative performance. This indicates that biotechnology MNEs tend to be more innovative than the pharmaceutical MNEs, It seems therefore that the industry of the firm, its size and its nationality together have some explanatory power in determining innovative performance. However, looking at the other equations in Table3, nationality is not consistently significant, suggesting that it is 'size' and 'industry', which are the most influential.

Table 3 here

With these controls and dummies in place, equations 3 to 9 in Table 3 introduce variables that relate specifically to the three hypotheses set out in the previous section. External knowledge flow variables to test Hypothesis 1 are ACAD, EXT FIRM, COLL FIRM and COLL ACAD, representing informal knowledge flows from academia and other firms to the innovating firms in the sample, and also collaborative knowledge sharing with academia and other firms. Used together in equation 4 these variables increase the adjusted R^2 with the controls and dummies alone, from 0.421 to 0.524, with the entire model significant at $p<0.005$. The significant variables in the equation are those capturing knowledge flows from academia (ACAD and COLL ACAD). The evidence thus suggests partial support for hypothesis 1, as knowledge flows from other firms do not appear to have a significantly positive influence on innovative performance.

Equation 5 shows that 'DIV TYPES', which measures the diversity in external knowledge flows to MNEs, is positive and significant causing an increase in adjusted R^2 to 0.631.[3].

This suggests that, even though the influence of knowledge flows from other companies is weak (compared to that from academia), it should not be discounted; diversity in knowledge flows

[3] As already noted two of the diversity measures are highly correlated with knowledge flow types variables (ACAD and EXT FIRM). However inclusion of the Diversity variables does not affect the sign or significance of the knowledge type variables- ACAD remains highly significant and positive whilst ext firm remains insignificant.

across different types of external entities does seem to enhance innovative performance even though the influence of academia seems to be paramount.

Before we focus on *cross border* knowledge flows within the MNEs, we note that intra MNE knowledge flows within the *same* country (as measured by the variable 'INT') is consistently positive and significant. This suggests that subsidiary embeddedness in the local or the national environment has both an internal and external organisational dimensions and that these dimensions reinforce each other in terms of influencing innovative performance .We will develop this point further in the concluding section of the paper.

Equations 7, 8 and 9 examine the impact of the intra-MNE cross- border knowledge flow variables, both informal knowledge flows as measured by patent citations (INT GLOB) and collaborative knowledge sharing as measured by co-authorship of patents (COLL IG), to test Hypothesis 2. In equation 7 these variables are added to the 'base model' (equation 5) of external knowledge flow type variables. The 'INT GLOB' variable is significant, increasing the adjusted R^2 from 0.631 to 0.639. However, the relationship is negative, suggesting that higher levels of internal global knowledge flows are detrimental to innovative performance. This result suggests that increased cross-border knowledge flows within the MNE, even when taking into account the existence of external knowledge flows, are harmful to innovation. Hypothesis 2 is thus not supported with respect to 'informal' knowledge flows. However, in equation 8, the COLL IG variable is positive and significant, causing a further increase in adjusted R^2 of the entire equation to 0.705. This suggests that, whereas increased intra-MNE knowledge flows across national borders are detrimental to innovative performance, those resulting in cross-border knowledge creation as evidenced by co-authorship of patents by inventors from different MNE locations, actually have a positive influence on innovation. Equation 9 introduces the variable DIV COLL, index of diversity in the collaborative/ knowledge sharing activities engaged by the MNE both internally and with external institutions. This variable produces a very large increase in adjusted R^2 to 0.830 and strongly suggests a high degree of interdependence between internal and external collaborative knowledge flows in stimulating innovation.[4]

III.2 Discussion

Two important findings emerge from this study. The first is that there is strong complementarily between internal and external tacit/ collaborative knowledge flows. Thus although external knowledge flow variables do exert a statistically stronger influence than internal knowledge flow variables, the explanatory power of the regression equations invariably increase significantly when both sets of variables are present. This conclusion is reinforced when we also consider the effect of diversity indicators, particularly by the strong influence of the DIV COLL

[4] A similar conclusion is suggested by the comparison between equation s 5 and 6 in table 3. We see that the adjusted R^2 is slightly higher in equation6 (0.633) where DIV ALL is used instead of DIV TYPES. This therefore indicates that a balance in knowledge flows *to include both internal* and external knowledge flows enhances innovative performance.

variable. This finding is consistent with suggestions in the literature that benefits can be accrued from the integration of dispersed knowledge assets to facilitate efficient innovation (Buckley and Carter. 2002; Kuemmerle, 2002). The strong influence of external knowledge flows confirms prior research linking subsidiary embeddedness in the local environment to its technological performance (Andersson and Forsgren 2000; Andersson, et el, 2001; Hakanson and Noble 2001; Phene and Almeida, 2003). The clear implication is that proximity matters in the subsidiary's knowledge creation /innovation activities; subsidiary's interactions are primarily with other organisations in its immediate geographical area. Our finding also supports the suggestion in the literature that subsidiary embeddedness is an important basis of its contributions to other units in the MNE; it stimulates and supports *internal* cross-border knowledge transfer and creation in MNEs (Hakanson and Noble, 2001; Subramaniam & Venkatraman, 2001; Phene and Almeida, 2003)

The second finding is that the influence of collaborative knowledge flows on innovative performance appears to be much stronger compared to that of informal knowledge flows. This is not surprising perhaps as collaborative knowledge flows are probably intentionally focussed on specific innovative or product development projects. The only instances where 'informal' flows exert a positive influence of innovative performance are captured by the variables ACAD and INT. ACAD refers to knowledge flows from academia whilst INT refers to intra MNE flows within the same locality/country as the patent assignee. Clearly the significance of ACAD may be due to the specialised scientific knowledge critical to the MNE innovative effort. On the other hand the positive impact of INT may indicate that spillovers occur primarily in a localised setting. The level of interactions between different MNE units in geographical proximity to each other would tend to high (e.g. interactions between R&D units and production / marketing units in the same country) and whilst such interaction are more likely involve collaborative /knowledge sharing flows, they may also increase the flow complementary informal knowledge useful to innovative activity.

Cross-border informal knowledge flows do not benefit from the advantage of proximity and would therefore be expected to have a somewhat weaker influence on innovative performance. Even so, that the influence of cross border informal knowledge flows is strongly negative is puzzling. A possible explanation is that an increase in cross-border patent citations may indicate that R&D effort by the (patenting) unit is more in the direction of adapting existing product or process produced by other organisational units rather than developing its own innovations. If we assume that adaptation of existing products and technologies produces few patents then there is good reason why cross-border citations may not be positively related to innovative performance as measured in this study. It may also be the case that a significant portion of patent citations do not represent genuine knowledge spillover but are due to 'gratuitous' citations (Jaffe et al, 1993). In other words, sub-units may proactively cite patents awarded to the other units and especially to the parent unit to create the appearance of technological conformity with the centre. Of course given the rigor with which patent data are complied by thus US patent office reduces the extent of this problem. Nevertheless there may be a significant element of 'noise' in intra-MNE patent citations due specifically to intra-organisational pressures within the MNE, rendering citation data relatively unreliable as indications of genuine knowledge flows or spillovers. This strongly suggests that the finding with respect to the negative effect of informal knowledge flows must be treated with a degree of caution.

CONCLUDING REMARKS

This paper has contributed to the growing international business literature on knowledge flows and the MNE. Whereas the extant literature is mainly concerned to explain the determinants of knowledge flows, this paper has focussed on the consequence of knowledge flows for innovative outcomes; an issue that has thus far received relatively limited attention. The empirical results of the paper largely confirm suggestions and expectations in the extant literature in that the paper provides support for a generally positive impact of knowledge flows on innovative performance. The findings of the paper relate only to the biopharmaceutical industry, there is much scope for future research to examine the impact of knowledge flows for innovative performance in other industries. A related implication is the validity of patent citations as an indicator of knowledge flows; it is possible that patent citations reflect knowledge flows more accurately in an inter- firm context compared to an intra-firm context; the latter may be subject to a higher degree of 'noise' as suggested in the previous section. Future research could beneficially investigate whether this is a serious source of bias.

The key implication of the present study for practitioners is that MNE-wide innovation is a managerially challenging phenomenon. It requires a deliberate effort to foster knowledge sharing and cross fertilisation across organisational units – whether inside or outside the MNE- 'Automatic' knowledge flows are rarely beneficial for innovation. Other than cases of highly localised spillovers or where the knowledge is of highly specialised character–there does not seem to be much positive influence from informal knowledge flows to innovation. The implication seems to be that cross border knowledge flows are more likely to be beneficial if the subunit (or at least the R&D personnel within it) is directly involved and participating in cross-border innovation. A related observation is that there is complementarily between external and internal knowledge sharing and that innovative outcomes are stronger when both are present. This is certainly consistent with the argument that external knowledge flows underpin the organisational differentiation within the MNE, which in turn creates a potential for creative intra-MNE knowledge sharing. Our findings reinforce the proposition that fostering-cross border knowledge creation must be premised on accepting the distinctiveness of subsidiaries in terms of their capabilities. It also requires an acceptance by the centre that, to a large extent, the main focus of subsidiary innovative activities will be localised and mainly directed to external rather than internal partners (Phene and Almeida, 2003). More broadly, there must be an acceptance of the view that subsidiaries are not merely ‘agents’ of the parent unit (O’Donnell, 2000). In part this necessitates that the centre does not necessarily expect subsidiaries to be ‘knowledge providers’ to other units as a routine function or ‘role’ but recognise that such flows should occur as a part of specific programmes of cross-border knowledge creation. The appropriate organisational mechanism for such knowledge flow/sharing is probably the formation of *temporary* project teams (see also note 1). Some authors have recently argued that MNEs are developing new organisational structure for innovative activity resulting in enhanced coordination and knowledge exchange between R&D labs (e.g. Gassmann and von Zedtwitz, 1999; Zanefi, 2000). Our findings tend to support this view but imply that the effective operation of the mechanism for cross-border innovation itself needs to be accompanied by a degree of organisational learning focused on managing the complex network of internal and external knowledge flows.

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Table 1: Definition and measurement of variables

Variable Name	Definition	Measurement
Dependent		
INNOV	Innovative Performance	Patents/R&D expend
Control		
NAT	Nationality of firm.	0=EU, 1=US
AGE	Age of firm.	Years since founding
SIZE	Number of employees	Nat. log # employees
Dummy		
IND	Industry of firm: biotech or pharm	0=pharm, 1=biotech
Independent: External Knowledge Flow 'Types' (EKT)		
IEKT (Informal knowledge flow)		
ACAD	Knowledge flows from uni, res inst & gov	Mean #citations per patent
EXT FIRM	Knowledge flows from external firms	Mean #citations per patent
CEKT (Collaborative knowledge sharing type variables)		
COLLFIRM	Collaborated patents with firms	% Total patents (5yrs)
COLLACA	Collaborated patents with academia	% Total patents (5yrs)
Independent: Internal knowledge flow variables (IKT)		
INT	Informal local knowledge flows	Mean #citations per patent
INT GLOB	Cross-border informal knowledge flows	Mean #citations per patent
COLL IG	Cross border collaborative knowledge flows	% Patents collaborated
Independent:	**Diversity in Knowledge Flows (DKF)**	
DIV TYPES	Diversity in external knowledge flows	Blau's index
DIV COLL	Diversity in Collaborative knowledge flows	Blau's index
D IVALL	Diversity of all knowledge flows	Blau's index

Table 2: The Correlation Matrix

	INNOV	NAT	IND	AGE	SIZE	ACAD	EXT FIRM	INT GLOB	INT	DIV ALL	COLL FIRM	COLL ACAD	C I
INNOV	1.00												
NAT	0.14	1.00											
IND	0.37	-0.12	1.00										
AGE	-0.38	0.18	-0.82	1.00									
SIZE	-0.57	0.29	-0.86	0.82	1.00								
ACAD	0.35	0.04	0.78	-0.72	-0.69	1.00							
EXT FIRM	0.38	0.12	0.44	-0.51	-0.46	0.42	1.00						
INT GLOB	-0.35	-0.06	-0.35	0.31	0.49	-0.31	-0.14	1.00					
INT	0.52	0.14	-0.04	0.15	-0.06	-0.15	0.40	0.15	1.00				

DIV ALL	0.50	0.04	0.71	-0.54	-0.61	0.61	0.82	-0.12	0.46	1.00			
COLL FIRM	0.02	-0.23	0.09	-0.08	-0.16	0.06	-0.22	0.37	-0.23	-0.07	1.00		
COLL ACAD	0.14	0.21	0.23	-0.25	-0.32	0.50	0.26	-0.26	-0.18	0.18	-0.14	1.00	
COLL IG	-0.11	-0.42	-0.21	0.29	0.16	-0.24	-0.30	0.61	-0.07	-0.16	0.69	-0.24	1
DIV COLL	0.09	0.06	0.21	0.00	0.15	-0.12	-0.06	0.22	0.23	0.19	-0.15	-0.28	-
DIV TYPES	0.29	0.06	0.82	-0.68	-0.69	0.92	0.46	-0.29	-0.18	0.69	0.14	0.35	-

Table 3. Multiple Regressions. Inter-organisational knowledge flow 'types' and Intra-MNE variables.

Variable	1	2	3	4	5	6	7	8	9
CONST	938***	1500***	1535***	1252**	1282*	1009**	782*	514*	1102*
NAT	181.50*	218.47*	100.29	100.14	101.81	152.37	152.22	166.66	21.46
	(0.35)	(0.42)	(0.20)	(0.19)	(0.19)	(0.29)	(0.10)	(0.32)	(0.06)
AGE	-1.67	-0.58	-1.51	-0.25	-0.61	-1.59	-1.12	-3.67	-0.49
	(-0.32)	(-0.11)	(-0.29)	(-0.05)	(-0.12)	(-.031)	(-0.22)	(-0.71)	(-0.12)
SIZE	-05.3**	-7.9***	-64.1**	-29.5**	-35.4*	-47.9***	-73.71*	-34.7*	-134.62*
	(-0.94)	(-0.62)	(-1.47)	(-1.16)	(-1.21)	(-1.32)	(-0.66)	(-0.31)	(-1.51)
IND		314.06*	481.02**	450.45**	381.80*	703.08**	386.15*	336.7*	842.4**
		(0.62)	(0.95)	(0.89)	(0.75)	(0.83)	(0.76)	(0.66)	(2.31)
ACAD			102.5**	104.58**	167.97*	58.46**	109.46*	76.2**	59.88**
			(0.52)	(0.53)	(0.86)	(0.49)	(0.56)	(0.39)	(0.81)
EXT FIRM			13.05	8.10	1.97	16.26	6.89	16.76	7.11
			(0.15)	(0.10)	(0.02)	(0.14)	(0.08)	(0.19)	(0.11)
COLL FIRM			-7.76	-3.34	-2.12	-5.90	-7.52	-2.74	-7.18
			(-0.12)	(-0.06)	(-0.04)	(-0.11)	(-0.13)	(-0.05)	(-0.19)
COLL ACAD			10.89**	8.26**	9.55**	6.60**	7.77*	4.20*	9.88**
			(0.59)	(0.45)	(0.52)	(0.46)	(0.42)	(0.23)	(0.81)
INT				109.20*	80.86*	62.3*	154.1**	198**	56.69*
				(0.41)	(0.31)	(0.36)	(0.59)	(0.75)	(0.28)
DIV ALL						2005.03*			
						(0.72)			
DIV TYPES					1024.4*				
					(0.41)				
DIV COLL									543.3**
									(0.81)
INT GLOB							-414.8*	-810**	-336.86*

							(0.31)	(-0.60)	(-0.33)
COLL IG								15.18*	
								(0.57)	
Adjusted R^2	0.365	0.421	0.524	0.629	0.631	0.633	0.639	0.705	0.830
Sig-f	0.016	0.014	0.003	0.001	0.002	0.002	0.001	0.001	0.000

Coefficient B, Standardised coefficient Beta in parenthesis

*** p< 0.10, ** p < 0.05, *** p < 0.01**