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Determinants of cross-national knowledge transfer and its effect on firm innovation

Masaaki Kotabe[1], Denise Dunlap-Hinkler[2], Ronaldo Parente[3] and Harsh A Mishra[4]

'The Fox School of Business and Management, Temple University, Philadelphia, PA, USA; [2]Widener University, Chester, PA, USA; [3]School of Business, Rutgers University, Camden, N], USA;[4]School of Business, State University of New York, New Paltz, NY, USA

Correspondence:
Masaaki Kotabe,
The Fox School of Business and Management, Temple University, 349 Speakman Hall, Philadelphia, PA 19122, USA.
Tel: +1 215 2047704;
Fax: +1 215 2048029;
E-mail: mkotabe@temple.edu

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Abstract

This study examines the determinants of international knowledge flow. From a resource-based perspective, it evaluates the impact of cross-national knowledge transfer on firm innovative performance. Based on 56,027 US patents owned by 53 selected firms in the US-based pharmaceutical industry, the results suggest that innovative performance is a curvilinear function of the international knowledge content used by a firm to innovate. As hypothesized, it was found that at (1) low and moderate levels of international knowledge content, a firm's strategy to transfer international knowledge improves its innovative performance, and at (2) higher levels of international knowledge content, there are diminishing marginal returns to transferring knowledge from overseas.

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Introduction

In multinational firms, international sourcing is recognized as an important part of global rationalization decisions to integrate multinational operations. While researchers have presented theoretical arguments and found evidence of the global strategic advantage or disadvantage from selective components, subassemblies and finished products sourcing strategies (Kotabe, 1998; Kotabe and Omura, 1989; Swamidass and Kotabe, 1993), research attention on the emerging area of firm knowledge transfer or knowledge sourcing is still scarce. In particular, the study of international knowledge transfer processes within multinational firms is at a relatively early stage (Buckley and Carter, 1999; Iwasa and Odagiri, 2004). Thus this topic is worthy of empirical investigation because it reaffirms the notion that firms are able to maximize innovative output when they renew their capabilities by transferring, sourcing, combining and integrating innovative knowledge not from the reallocation of capital and other assets, but through the transferring or sourcing of knowledge from strategically advantageous international locations (Bresnman *et al.*, 1999).

The innovation literature emphasizes two opposing views regarding the transferring of international knowledge. The first school of thought proposes that innovation is a learning process requiring greater specialization (Chiesa, 1996; Cohen and Klepper, 1996), because its elements are path-dependent (David, 1988; Dosi

et al, 1991; Redding, 2002) and are developed gradually and cumulatively over time (Lundvall, 1992; Leonard-Barton, 1995). In this school of thought, learning refers to a tacit component of knowledge. Knowledge reservoirs are accumulated at the level of the firm, and are continually being restocked by new ideas (Dosi, 1988; Teece, 1988; Leonard-Barton, 1995). It is argued that to achieve scale economies in R&D, geographical proximity at a single location, preferably within a regionally or a nationally concentrated knowledge cluster, is preferred because it provides a fertile ground for efficiency, specialization and opportunities for in-depth problem-solving in innovation.

The counter-argument to this view is that cumulativeness and path dependence of innovation lead to risks of 'lock-in' into technological and institutional cul-de-sacs (Michie, 1998; Redding, 2002). Knowledge diversity is viewed as beneficial because it safeguards institutions and networks from becoming 'locked into' the 'old' technologies. Diversity increases the pool of know-how the firm can access, which further stimulates the innovative process (Leonard-Barton, 1995; Classman, 2001). Moreover, new strategies emerge from dealing with diverse environmental uncertainties and complexities (Simon, 1985; Kaufman, 1995; Patel *et al,* 1996; Andriani, 2001).

In this research, we posit that international knowledge transferring or sourcing by firms confirms the latter argument. Researchers have not empirically addressed the notion that firms use the diversity inherent in cross-border knowledge to generate greater innovations. Much research in this area is case-based and theoretical in nature (e.g., Classman, 2001). To make meaningful contributions to managers in charge of international knowledge transfer decisions, we utilize the resource-based view in examining the determinants of outsourcing knowledge from cross-national locations and its effect on innovation. The results of this study are particularly important because, while many organizations recognize that global integrated sourcing strategies offer potential gains in performance, few have well-developed processes put in place (Trent and Monczka, 2002). Thus, to further our understanding of international knowledge transfer, a conceptual framework is developed and is empirically tested with time-series data spanning nine years. Our tests focused on US patent data in a single industry, the US pharmaceutical industry.

This paper is organized as follows. In the next section, we provide a literature review. Then, we present our model and research hypotheses. The subsequent section explains the data, followed by the empirical results. Finally, we discuss the findings, implications and limitations of our research.

Literature review: international knowledge transfer

Firms, both domestic and multinational, engage in international sourcing of knowledge. While the resource-based view of the firm has attracted considerable discussion on knowledge by management scholars (Barney, 1991; Mowery *et al.,* 1998; Barney *et al.,* 2001), there is a conspicuous dearth of empirical work that tests the value of knowledge transfer to a firm. Even in the general arena of strategy research, amidst a score of empirical work, the issue of measuring knowledge and its value for firm performance remains generally evasive and intellectually challenging for strategy researchers (Cohen, 1998; Ambrosini and Bowman, 2001). This stream of research is even less explored in the international management literature, despite the fact that the MNE has long been argued as an integrator of knowledge (Bartlett and Ghoshal, 1989, 1998). As a principal agent of globalization, it is implied that an MNE's umbrella of ownership and control encourages an integrated policy of sourcing or transferring geographically dispersed knowledge bases from across nations.

Most research on the topic of innovation and studies on multinationals, up until recently, have implicitly assumed that, for certain efficient reasons, innovation is and ought to be a centralized activity at the parent location in which there is a limited flow of knowledge across borders (Vernon, 1966; Dunning, 1980; Cantwell, 1989; Patel and Pavitt, 1991). Their argument against decentralization of the MNE innovation function is based on the need for physical co-location of R&D (Cohen, 1998), importance of home market (Vernon, 1966; Dunning, 1980; Cantwell, 1989) and home country competitiveness (Porter, 1990; Patel and Pavitt, 1991; Sakakibara and Porter, 2001). Counter to this argument, another emerging stream of research maintains that, although the dissemination of knowledge is indeed a complex activity, there are significant gains in competitive advantage to be achieved through the *intra-* and inter-firm sourcing or flow of international knowledge (Lord and Ranft, 2000; Iwasa and Odagiri, 2004).

Researchers suggest that the innovative role of subsidiaries in multinational corporations has become significant in recent years, with relatively smaller yet increasing decentralization of the innovative function (Mansfield and Romeo, 1980; Hakanson and Zander, 1988; Cheng and Bolon, 1993; Chiesa and Manzini, 1996; Asakawa, 2001). Proponents of decentralized innovation suggest that ideas flow more easily when firms view subsidiaries not as isolated outposts, but rather as extensions to the organization's primary strategic domain (Birkinshaw and Hood, 2001). The following benefits can be expected from decentralizing foreign R&D:

- tapping into different national systems of innovation (Robinson, 1988; Cantwell, 1992);
- gaining access to new lines of technological diversification reflected in local markets (Cantwell, 1992; Cantwell and Kotecha, 1997; Iwasa and Odagiri, 2004);
- obtaining more varied flow of ideas, products, processes and technologies (Hakanson and Nobel, 2001);
- creating more rapid and effective communication while at the same time reducing developmental costs (Chiesa, 1996);
- capitalizing on location-specific advantages through the international division of labor among foreign R&D labs (Lorenz, 1983); and
- improving responsiveness to local needs, in terms both of time and of relevance through quality access to local technical support (Caves, 1982; Robinson, 1988; Dunning, 1993; Chiesa, 1996), since the firm is able to get 'closer to customer' (Casson *et al.*, 1992) and take advantage of positive regulatory environments and favorable foreign government incentives (Caves, 1982; Dunning, 1993).

Although scholars have argued both for and against positive outcomes resulting from the transfer of knowledge between parent and foreign subsidiaries, a substantiation of theoretical discourse on cross-national knowledge flow continues to be largely unexplored. To extend our understanding regarding the decentralization of innovative activities across nations within MNEs, our study empirically examines the performance implications of cross-border knowledge transfer, and sheds new light on - and perhaps bridges - the ongoing theoretical debate between the 'strategic-positioning' and 'resource-based' views. For international business researchers and managers of MNEs, there are direct implications. By strategically positioning its innovative efforts along cross-national locations, an MNE may be able to gain by continually transacting and synthesizing diverse knowledge to enhance and renew its resources.

Although some frameworks have been offered that attempt to describe, characterize and explain the knowledge linkages between the parent firm and its subsidiaries (e.g., Bartlett and Ghoshal, 1989, 1998; Asakawa, 2001), there is no integrating framework that satisfactorily explains the internationalization of innovation by MNEs, or international transfer of knowledge by firms. According to Zander (1997: 211):

How managers handle the trade-off between improved quality of innovation and the difficulties associated with international innovation is yet to be more fully researched. Similarly, the relative importance of local and global influences in the innovation process remains to be studied more in-depth.

Our study recognizes the nature of these research gaps. The corresponding contribution of this research is that it attempts to fill them, as outlined in the Appendix. This research supports the view that within MNEs there is a greater flow of international knowledge as subsidiaries have begun to play an important role as centers of learning (Ghoshal and Bartlett, 1988; Gupta and Govindarajan, 1991; Asakawa, 2001; Iwasa and Odagiri, 2004). This argument applies even more to MNEs located in developed countries (Dunning, 1998), and those especially located in the triad zone countries of the US, Japan and Europe (Asakawa, 2001). Our proposed theoretical model presented in Figure 1 summarizes the hypotheses outlining the determining variables of international knowledge transfer and the effect of such use on the innovative performance of firms.

Theory and hypothesis development

The underlying theory of our framework is the resource-based view of the firm (Wernerfelt, 1984), where strategic resources like patents, know-how and strong reputations serve as a powerful differentiation from competitors (Barney, 1991). The rationale is that firms cannot achieve competitive advantage by possessing non-strategic resources that can be easily acquired and sold, such as slack capital (Hult *et al.*, 2002). Researchers have noted the positive attributes of internationalization/diversification on firm performance (e.g., greater

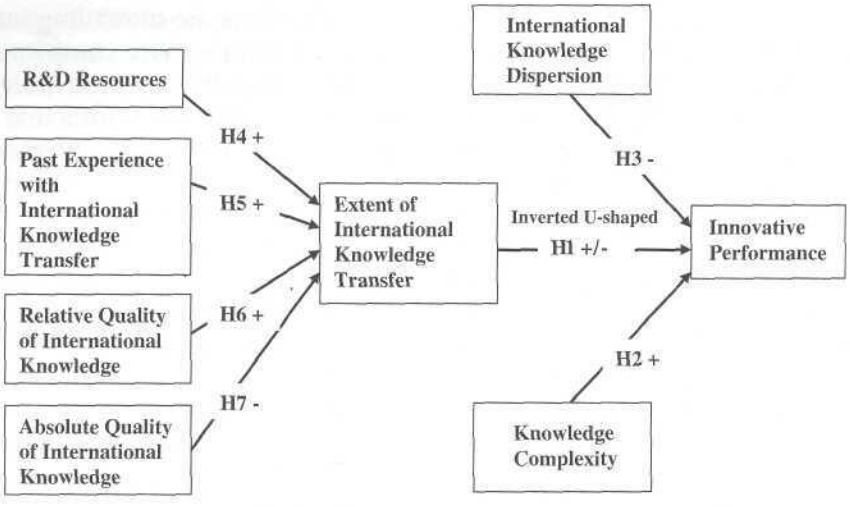

Figure 1 International knowledge transfer and innovative performance framework.

firm growth potential; Hitt *et al.*, 1997). For instance, managers of internationally diversified firms have been shown to have richer knowledge structures than those of domestic firms (Calori *et al.*, 1994), which in turn aggregate to richer knowledge structures (Walsh, 1995) and stronger technological capabilities at the firm level (Cohen and Levinthal, 1990). Stronger technological capabilities (March, 1991) in turn create new ways of doing things, which fosters innovation (Mezias and Glynn, 1993; Hult *et al.*, 2002).

Multinationals with their cross-national presence derive benefits by synthesizing different network-specific knowledge located among clusters in different countries (Porter, 1998; Porter and Stern, 2001). According to Vernon (1966), not only is the home market the source of stimulus for the innovating firm, but it is also the preferred location for its actual development. Bartlett and Ghoshal (1989) and Hedlund (1986) argued that multinationals are not simply exploiters of home country knowledge, but are also efficient networks accessing technology from many locations and transferring and sharing such knowledge across the organization. In addition, Kogut's (1989) research supports this view of multinationals possessing the ability to learn abroad and apply knowledge in different parts of the organization.

Next, we develop a theoretical work around our central hypothesis that suggests that the benefits from international knowledge integration are realized to the extent a firm can successfully deal with the accompanying knowledge complexity and coordination problems.

Knowledge transfer and innovative performance: a curvilinear relationship

The resource-based view (RBV) offers opportunities to investigate the relationship between the international knowledge transfer and innovative performance. The RBV suggests that firms should be able to outperform their competitors by utilizing strategic assets and capabilities (Anon, 1998; Hult *et al.*, 2002). According to Barney (1991), strategic assets and capabilities are valuable, rare and difficult to imitate. Building on the RBV, the firm's ability to learn from, transfer, or source knowledge from its cross-border operations can serve as a strategic resource. An important benefit of international knowledge transfer arises from the notion of utilizing and acquiring complementary knowledge resources located across nations to enhance and/or sustain the firm's competitive advantage.

Researchers maintain that there are two broad types of knowledge input required by firms to innovate. The first is the knowledge related to the user needs, and the second is the technology-related knowledge inputs (Rothwell *et al.*, 1974; Cooper, 1979; Ogawa, 1998). Within multinational firms, user-need related knowledge is located closer to the host market. Firms that use a 'lead-user-need process' gather information about both the needs and solutions, not from a random or typical set of customers, but rather from users at the leading edges of the target domain and users in other markets that encounter comparable problems, but in a more radical form (Lilien *et al.*, 2002). Multinational subsidiaries internalize this user-need related knowledge through proximity to and

participation in the local market. Given that MNEs have multiple subsidiaries operating in different national environments, the MNE must respond to the various contingencies presented by the multiple user environments in which it operates. These contingencies have been categorized in the multinational management literature as 'forces for national responsiveness' (Ghoshal and Nohria, 1993). Within multinational corporations, technology-related knowledge is acquired, developed locally or transferred from different international locations. Parent organizations, as the supplier of knowledge, equip their subsidiaries with the necessary technology to give them a competitive edge. Subsidiaries often transfer a larger portion of the technology-related knowledge from their parent company especially during the early/initial phase of multinational evolution, when profitability and cost considerations are the primary driving factors (Caves, 1971; Hymer, 1976; Kogut and Zander, 1993; McKern, 1993).

Another important benefit derived from the unique knowledge transferred or sourced from different international locations is that knowledge, on a broader level, is socially and culturally embedded in the nation's political, economic and innovation infrastructure (i.e., human, financial, scientific, technological and public policy resources: Porter, 1990, 1998; Dunning, 1998; Porter and Stern, 2001). International management researchers maintain that an MNE innovates by integrating and acquiring these culturally diverse knowledge bases from multinational locations to its own core capabilities. In sum, whether the benefit to MNE geographical dispersion and concentration, within cluster-specific, innovative environments, is the ability to synthesize network-specific, complementary, or socially and culturally embedded knowledge, researchers postulate that multinationality enhances the firm's drive, direction and pace of innovative product development (Prahalad and Doz, 1987; Bartlett and Ghoshal, 1990; Porter, 1990, 1998; Cantwell, 1992; Porter and Stern, 2001).

Past research findings have been mixed. While some have found a positive relationship (Grant, 1987; Daniels and Brackner, 1989; Haar, 1989; Kim *et al,* 1993; Zahra *et al.,* 2000), others have found/suggested no relationship (Kumar, 1984; Morck and Yeung, 1991) or a nonlinear relationship between international diversification and firm performance (Geringer *et al,* 1989; Hitt *et al,* 1997; Gomes and Ramaswamy, 1999), neglecting to consider the extent to which international knowledge is transferred or sourced from diverse locations. The theoretical and empirical perspectives that examined the 'curvilinear aspect' of international knowledge transfer, in this study, may facilitate our understanding that transferring higher levels of international knowledge does not necessarily amount to higher net innovative benefits, because of the higher accompanying costs associated with managing such excessive diversity. In the current study, we predict that a critical issue in transferring a higher level of knowledge is that there will be a subsequent reduction in the quality of knowledge. This understanding is intended to offer a step in the direction of the existing literature that has stressed that the improved quality of innovation from the integration of international technological capabilities is needed (Zander, 1997).

The argument that creativity and new ideas spring from the interaction or recombination of different and sometimes deliberately conflicting knowledge sets has found acceptance in the knowledge literature (e.g., Simon, 1985), social network literature (e.g., Granovetter, 1973), and the emerging scientific literature on complexity (e.g., Kaufman, 1995). Theories in cognitive psychology argue the dynamic interaction of diverse perspectives results in cognitive performance (Patel *et al,* 1996; Madhavan and Grover, 1998). The ability to innovate suffers if shared experiences are not being renewed (Gersick and Hackman, 1990).[1] From these theories, we argue that the interaction between cross-cultural and cross-functional knowledge from local and international sources will enhance the innovative outcome of a firm up to a certain point, and then the benefits will start to diminish. While it may be clear that there are several gains to be made by transferring or sourcing knowledge internationally, dealing with highly dispersed knowledge bases also increases the variety of ideas or mental models to which a firm is exposed. There are obstacles encountered in managing culturally dissimilar and distinct knowledge sets, because each set has a variety of unique problem-solving issues that may exceed any potential returns that utilizing international knowledge content may bring.

We argue that transferring knowledge at higher levels will result in diminishing returns to innovative performance. Below these levels of international knowledge diversity, elaborate research resource investments are neither critical nor typical. The resources that the firm has are readily

deployed to successfully integrate international knowledge, and local research personnel are likely to absorb the additional responsibility of recombining new international knowledge. In contrast, when the level of transferred international knowledge is high (i.e., an increased number of unfamiliar locations from which knowledge is transferred), firms need to adopt complex and costly integrating techniques. We argue that while there are several gains to be made by transferring knowledge internationally, there is some optimal level of local and international knowledge beyond which there are negative marginal returns associated with the effective communication, coordination (Zander, 1997) and synthesis of such knowledge.

Summarizing from the discussion above, the central hypothesis of this study is based on the idea that the relationship between international knowledge transfer and innovative performance is nonlinear, comprising a portion of expansionary growth where incremental costs can eventually exceed incremental benefits. More specifically, our study is interested in determining how the levels of international knowledge transfer influence innovative performance. We postulate that the net positive benefits of local-international knowledge diversity rise faster than the associated costs up to a certain point. At this point, we argue that the coordination costs start to exceed the benefits. Hence we propose the following hypothesis:

> Hypothesis 1: The relationship between international knowledge transfer and innovative performance will be nonlinear with innovative performance increasing up to an optimal level beyond which higher levels of international knowledge transfer lead to a decline in innovative performance.

Following the discussion above, the nature of sourcing of diverse knowledge resources also brings about three critical knowledge dimensions that organizations must consider: tacitness, specificity and complexity. Specifically, the transferring of knowledge complexity requires a high degree of reciprocal interdependence, integration and coordination. It also offers a unique combination of resources that is not easy for competitors to imitate (Parise and Henderson, 2001). In our model, we address knowledge complexity as an independent variable and a critical input into the innovation process affecting the innovative output of a firm. Kogut and Zander (1992) studied innovation, and suggested that the innovative processes involve some measure of tacit knowledge. We assume that the transfer and application of tacit knowledge 'in part, creates innovations that lead to patents' (Almeida *et al.*, 2002: 152). In our research, we expect that patent knowledge is an intermediate form of knowledge complexity in the continuum between the explicit and the tacit type.[2] Past research has more commonly adopted a bipolar categorization of knowledge type tacit and explicit knowledge. While categorizing knowledge in this way is useful (Kogut and Zander, 1992), its bipolar distinction does not portray the true complexity of knowledge, because it involves a range of both tacit and explicit components (Howells, 2000).

Following Winter (1987) and Kogut and Zander (1993), we use the dimensions of codifiability, teachablity and complexity, and postulate that some type of knowledge may be high or low on one dimension or another. The dimension of teachability is not pertinent to patent knowledge, because the creator of such knowledge is remote from the assimilator. Thus each patent is expected to vary in its level of codifiability as well as its complexity. Since patents are considered largely codified knowledge, the degree of knowledge complexity remains the outstanding characteristic of patent type knowledge and therefore becomes an important variable. Based on the theory of creative abrasion on innovation, we argue that the greater the knowledge complexity a firm deals with, the greater knowledge about various perspectives the firm may internalize. An exposure to such complexity in turn is likely to increase the firm's absorptive capability to continually acquire newer and/or broader technology bases (Cohen and Levinthal, 1990). Based on the organizational learning literature, firms that are capable of learning from a complex/diverse resource base will not only reduce the risk of their technologies being 'locked out', but will also increase their likelihood of better innovative performance (i.e., the firm's ability to quickly respond to and anticipate the shifting demands of consumers with the generation of newer technologies). Accordingly, we hypothesize:

> Hypothesis 2: Firms that process greater knowledge complexity have better innovative performance than those that process less knowledge complexity.

In addition to the issue surrounding knowledge complexity, firms may differ in their configuration

of nations from which they transfer knowledge. The assumption, in our model, is that knowledge from a particular national location embodies or reflects in some form its national culture with characteristic mental models. We argue that the extent of dispersion in the national origins of knowledge plays a significant role in affecting innovative returns to international knowledge flow. Most prior research has attempted to understand or explain, through internationalization and foreign direct investment theories, the international diversification and entry mode decisions of firms (i.e., the location patterns of firms) (Kogut and Singh, 1988; Andersen, 1993; O'Grady and Lane, 1996; Dow, 2000). The strategy literature on learning suggests that it is fostered by diversity in experience, whereas repeated spirals of competition and cooperation within the familiar setting lead to blindness to opportunities and threats that transcend the specific setting (Levitt and March, 1988; ; Cohen and Levinthal, 1990; Leonard-Barton, 1992, 1995; Abrahamson and Fombrun, 1994). Firms with relatively few challenges have narrower ranges of experience, and narrower mental models. Researchers argue that such narrowness or reduced 'absorptive capacity' negatively hurts performance in the long run (Miller and Chen, 1996; Stock *etal,* 2001).

Our research supports the argument that a synthesis of diverse knowledge transferred or sourced from cross-national locations will put a downward pressure on innovation because of the potential increased negative concomitant costs (e.g., communication and coordination transactions) that result from obtaining such specific, complementary and culturally embedded knowledge. Quite interestingly, researchers studying international diversification and performance (Geringer *et al,* 1989; Hitt *et al,* 1997; Gomes and Ramaswamy, 1999; Zahra *et al,* 2000) neglect to consider the degree of knowledge that is transferred from international diverse locations. Operating in diverse national environments that are initially unfamiliar - in terms of customers, suppliers, rivals and partners - not only triggers failures, but also increases the incentives to seek (Simon, 1955) new strategies/solutions that further enhance the firm's technological capabilities and innovative processes (Levitt and March, 1988; Miller and Chen, 1996; Glassman, 2001). Unfortunately, implications for transferring high levels of international knowledge dispersion include an increase of knowledge diversity beyond acceptable levels for effective communication and coordination (Hitt *et al,* 1997). Therefore our corresponding prediction is that firms prefer fewer, higher-quality international knowledge sources to learn from. These choices will enable the firm to achieve an acceptable threshold of international knowledge diversity. Thus we hypothesize that:

> Hypothesis 3: Firms that transfer knowledge from fewer internationally dispersed locations have better innovative performance than those that transfer knowledge from more internationally dispersed locations.

Next, we examine the firm resources and capabilities associated with the level of international knowledge transfer, and develop specific hypotheses regarding the determinants of international knowledge flow.

Determinants of international knowledge transfer

R&D resources

Firms derive competitive advantage by achieving efficiency of R&D operations (i.e., expanding and exploiting potential scale economies: Ghoshal, 1987; Sakakibara and Porter, 2001). A large body of empirical work has examined the relationship between R&D intensity and firm performance. It is relatively well established among researchers that increasing R&D intensity increases firm performance (Scherer, 1982; Franko, 1989; Deeds *et al,* 1997; UK Department of Trade and Industry, 2002). Critics of this research stream have argued that there are other, more difficult to measure, variables that may cause better firm performance. Considering this limitation, a smaller body of research has focused on the effect of research-related resource inputs on innovative output instead of firm performance. The general conclusion is that resource allocation, depending on how its activities are organized (e.g., decentralized, networked, or integrated), can have a significantly positive impact on the firm's ability to innovate (Franko, 1989; DeSanctis *et al,* 2002). A majority of researchers in this stream maintain that the greater the resources that the firm preferentially allocates to innovative efforts, the greater the innovation. This is particularly evident in the pharmaceutical industry, where long-term R&D investments are vital to future performance (Taggart, 1991; UK Department of Trade and Industry, 2002).

In our research, we argue that inconsistencies in a direct relationship between R&D resources and

innovation can be better explained when we consider how a firm selectively uses its resources, in the face of resource constraints, to transfer knowledge of different kinds as inputs to create innovation. In that sense, learning to integrate diverse knowledge bases may require greater experience and commitment of resources by the firm. We postulate that the nature of resource utilization is a mediating variable between resources available and innovative output and, furthermore, that resource utilization is reflected in the nature of knowledge transferred or sourced as a knowledge input. In general, there exists an internal market for a firm's resources (Cheng and Kesner, 1997) to transfer knowledge from one physical location to another or, in our case, to incorporate new knowledge in the process of innovation. Transferring international knowledge to be used as an input for innovation may invite greater uncertainties, such as resolving unfamiliar mental models. Therefore the transferring of international knowledge is likely to be a positive function of the amount of resources devoted to its development. Put differently, a firm that successfully devotes and invests in greater resources available for international knowledge transfer is more likely to employ international knowledge as an input into the process of innovation. Accordingly, we hypothesize:

Hypothesis 4: Firms with greater R&D resources will transfer international knowledge to a greater extent.

Past experience with international knowledge transfer

It can be reasonably argued that knowledge and innovation are firm-specific constructs, and the role of firm history is critical in firm-level comparisons. Learning and technological change include strong elements of path dependence (David, 1988; Dosi *etal.*, 1991; Powell *etal*, 1996; Redding, 2002). Learning is also cumulative at the level of the firm, which builds upon its existing knowledge base and other assets (Dosi, 1988; Teece, 1988; Cohen and Levinthal, 1990). The important benefit of such specialization, or what others have termed Teaming by doing' (Arrow, 1962), is the learning curve (von Hippel, 1998). As firms become beneficiaries of experience, they apply lessons from one innovation process to another. In our study, we postulate that, prior to learning, there are diminishing returns to using international knowledge.

In contrast, researchers also argue that extensive past experience with particular knowledge may result in greater inertia for change or learning, owing to the recipient's absorptive capacity to assimilate new knowledge. In the case of strong in-house innovative capacity of the firm, established mental models prevalent among innovators will be the norm, and new international knowledge mental models may have less acceptance in reality, thus becoming obstacles to realizing the benefits of knowledge diversity. In other words, continuous investing in past knowledge experiences increases the firm's risk of being 'locked out' from acquiring and/or investing in new technologies. Despite this argument, researchers argue that past experiences acquired through handling increased international knowledge diversity should give rise to higher-quality products and more efficient processes Qoyner and Onken, 2002), since there is a general familiarity with the diverse mental models involving internationally transferred knowledge. We postulate that such familiarity will create a tolerance for ambiguity and appreciation of diversity as the norm. An appreciation of knowledge complexities as the norm may enhance firm confidence to use or source additional international knowledge from diverse locations in the future. Few researchers have empirically examined the processes at work (e.g., past experience) during the international knowledge transfer process (Joyner and Onken, 2002). Hence:

Hypothesis 5: Firms with greater past experience with transferring international knowledge engage in international knowledge transfer to a larger extent in the current year.

Absolute and relative quality of international knowledge

Next, we examine the impact of the quality of international knowledge content based on the extent of international knowledge transferred. A firm ventures into the international arena seeking to acquire and/or invest in knowledge resources of higher quality. Some firms rely on the large quantity of international knowledge sources for the benefit of knowledge diversity, while other firms seek the high quality of international knowledge from a limited number of sources for the benefit of specialization.

Transferring knowledge resources that carry a better reputation (i.e., they are new generation technologies) helps firms from becoming too dependent or 'locked into' their own aging technological and institutional resource bases (Michie,

1998; Redding, 2002). Familiarity with local or domestic knowledge will prevent a firm from sourcing unfamiliar international knowledge resources (i.e., firms incrementally begin to transfer knowledge from countries that are 'psychically' closest to them: Qohanson and Vahlne, 1977; Kogut and Singh, 1988; Andersen, 1993; Dow, 2000). The incremental strategic process of using familiar knowledge has been found to positively affect firm performance (Evans and Mavondo, 2002). We therefore postulate that, unless the reputation of a particular piece of international knowledge is valued, well known, or well cited, a firm will choose only those knowledge resources that have better quality than locally available knowledge sets (Robinson, 1988). Thus, in order to compete with technology from familiar local or domestic networks, knowledge resources need to be higher in quality. Hence:

Hypothesis 6: The higher the quality of international knowledge relative to local knowledge sources available, the greater is the extent of international knowledge transferred by a firm.

Firms that use or transfer a higher quality of international knowledge are likely to obtain knowledge from fewer international locations. Seeking to gain from the best available overseas knowledge, they tend to narrow their choices to knowledge resources that are ostensibly higher in quality. Under the assumption that international knowledge of higher quality is also more complex and requires greater resources to integrate, it can be postulated that, by choosing fewer diverse knowledge settings, firms reduce the costs that they would otherwise incur should they move into many unfamiliar territories. Accordingly, the higher the quality of international knowledge, the fewer the number of different knowledge resources transferred or sourced by a firm. Hence:

Hypothesis 7: The higher the absolute quality of the international knowledge, the less is the extent of international knowledge obtained by a firm.

Methods

Researchers maintain that while the value of knowledge cannot be directly measured, it is possible to measure outcomes (e.g., changes in profitability, efficiency or rate of innovation) that follow from knowledge efforts. By extending past research efforts that have used patent citation analysis as an indicator of knowledge transfer (Patel and Pavitt, 1991; Jaffe *etal*, 1993, 2000), our paper is intended to contribute to the empirical literature that has linked 'knowledge assets' or 'knowledge capital' measures such as R&D investment, patent counts and citation-weighted patents with the market value of the firm. There is a wide range of literature that has tested the positive relationships among different types of 'knowledge capital' investments and how they also positively affect firm-level performance (Griliches, 1981; Cockburn and Griliches, 1988; Trajtenberg, 1990; Hall, 1993; Hall *et al,* 2005).

Currently, many scholars use the methodology of patent citation analysis pioneered by Jaffe *et al.* (1993) to track knowledge flows and examine the extent to which knowledge spillovers are geographically localized (e.g., Almeida *et al.,* 2002; Song and Shin, 2002; Song *et al.,* 2003). Along these lines, a key feature of examining patent data, in this study, is that patent citations are capable of identifying a link between the technical ideas embedded in the current patent and its prior inventions (Frost, 2001). In the words of Jaffe *et al.* (1993: 580), 'in principle, a citation of Patent X by Patent Y means that X represents a piece of previously existing knowledge upon which Y builds.' This methodological process allows for researchers to track the association or knowledge building process between Patent X and Patent Y across technological, organizational, geographic and temporal aspects (Jaffe *et al.,* 1993; Frost, 2001). Furthermore, it allows researchers to consider such citations as evidence of cross-border knowledge transfer.

By utilizing this methodology, Jaffe *et al.* (2000) found additional evidence about the unobservable process of knowledge transfer and the relationship of patent citations to that process. Their results provide further empirical support for researchers who use aggregate citation flows as proxies for knowledge-spillover activities between organizations and between countries. According to Almeida *etal.* (2002: 151): 'Patent data have received much attention because they provide detailed information, are systematically compiled and are available continuously across time.' Patent data are known to contain detailed information, and therefore make good indicators of technological and innovative capacities (Hall *et al.,* 2000). Patent document also contain other information on the patenting firm, technology types, inventor and geographic location (Almeida *et al.,* 2002).

In keeping with Jaffe *et al.'s* (1993) methodology and the most recent patent research, we traced knowledge transfer activities from strategically advantageous international locations. To better understand the level of technological significance of patents, this research investigated how the transfer of cross-national patent knowledge, derived from the geographic information contained in a patent citation (Jaffe *et al,* 1993; Frost, 2001), affects the innovative performance of firms.

Our overall reasons for undertaking patent-based analysis are varied. The transferring or sourcing of patent knowledge is a prevalent practice in technology-intensive industries such as the pharmaceutical, chemical and electronics industries. Sourcing of this kind is frequently done across borders without incurring the costs stemming from geographical considerations. Another reason for undertaking patent-focused analysis comes from the strength of using patents to indicate inventive output (Pavitt, 1988). Firms such as CHI Research, Inc. have even recognized the value of patent portfolio analysis: in 1998 CHI began to offer an on-line tool, referred to as Tech-Line, to its customers. By using patent data, the firm is able to perform company-to-company technology comparisons, rankings within an industry and future market value/performance analyses (Anon, 1998).

In our research the term *prior art* is the *actual referral* in a new patent to past-published patented knowledge, which is considered in our study as an equivalent usage and transfer of such knowledge (listed as the prior art in our patent data). This referral implies a potential opportunity or sunk costs borne by the inventing firm.[4] This argument in turn implies that the realization of these opportunities or sunk costs will eventually show up in the innovative performance or valuation of new patents that transferred prior art knowledge as an input. This argument is further supported by Almeida (1996). According to Almeida, the list of citations to other patents contained in the patent document represents the technological antecedents to the particular innovation, and these citations enable researchers to observe interfirm technology building.

Lastly, the effect of knowledge transfer on the innovative performance of a firm is closely linked to the following question: How valuable are a firm's invented patents? On these lines, this study develops a new, qualitative patent-based measure of innovative performance, which improves the measure of patent-count-based measures alone (Carpenter and Narin, 1983; Albert *et al,* 1991). The need to include qualitative or value indicators of patents that would enhance the overall relative measure of innovative performance aptly addresses the concern raised by Kotabe (1992) in his study of US and Japanese patent systems. These measures were developed from the US patent data to test our hypotheses.

Sample and data collection

The sample for this study included US-based multinational firms. Patent data were collected from firms in the US pharmaceutical industry. Firms within this industry were selected for three reasons:

(1) The industry is technology-intensive.
(2) Most multinational corporations in this global industry are of US origin.
(3) US patent data are representative of global inventive activities (i.e., most significant innovations are patented in the US: Patel and Pavitt, 1991).

The unit of analysis was the individual patent, and the level of analysis was the firm.

Three sources were used to collect data on these firms: the Compustat database for SIC 2834: Forbes' annual list of the top 100 US international firms; and CHI Research, Inc., a private patent data source. A list of 74 registered organizations was created from these resources. From this list, 57 firms were selected, leaving out small laboratories or university research bodies. Based on the study's interest in cross-national knowledge transfer, these entities were not considered because they did not have sufficient cumulative patent output. In cooperation with CHI Research, Inc., raw data on 56,027 US patents owned by these 5 7 selected firms in the US pharmaceutical industry were obtained. Information on the firms' cross-ownership helped to further consolidate the 57 entities into 53 independent firms.

For each of the 53 firms, information was extracted from data on individual US-based patents. The patent data were available for the 1980-1998 period, on the application year, grant year, first inventor's country, number of times a particular patent was referenced subsequent to its publication by other patents over the years until 1998, and prior art patents listed on each patent with their first inventor's country information. Information on each patent's first inventor's country location helped identify patents whose invention took place primarily within the US. Let us call

these patents US-based patents, as distinct from US-registered patents. For the firms, information extracted from data on individual US-based patents was then used to construct firm-level variables.

These data were then used to construct firm-level variables. A longitudinal data design was used to collect data over nine time periods (1990-1998). Data were collected on the application year, grant year, first inventor's country, number of times a particular patent was referenced subsequent to its publication by other patents over the years until 1998, and prior art patents listed on each patent with their first inventor's country information.

Measures

Dependent variable

Innovative performance (Innov__Perf) at the firm level was measured as a ratio of the number of cross-citations of patents from previous assignees or knowledge transfer partners to the number of patents received by a firm. Patent cross-citations between knowledge transfer partners in this study refers to a knowledge transfer map that highlights or measures how important or dominant a firm is in its specific patent activities in a given technological or knowledge-based area compared with its external environment. This overall patent-based measure was constructed by cumulating the number of patents granted to a firm and each patent's yearly frequency of citations by the industry for a period of nine years (1990-1998).

Independent variables

Independent variables were constructed from the raw patent database for the 1991-1995 period using the application year as their basis. Adding this time lag adequately captured the longitudinal effect of various independent variables on the firm's innovative performance (Innov_Perf) (cf. Kotabe, 1992). The extent of *international knowledge transfer* (Int_Know) was measured by taking the ratio of the *international/foreign prior art* (For_Know) to the *total prior art* (ForJKnow + US_Know) listed on a firm's patents for each application year. *International/foreign knowledge* (For_Know) was measured as the number of *prior art* citations with location of the first inventor being a country other than the United States. *Domestic or US knowledge* (US_Know) was measured as the number *of prior art* citations on each patent with location of the first inventor being based in the US. *Knowledge Complexity* (Know_Cpx) was measured as the processing time that a patent took, in years, to be processed by the patent examiner(s) in the patent office. We controlled for the difference in processing times that different countries may have by examining US patent applications alone (Kotabe, 1992). *International knowledge dispersion* (Know_Disp) was measured by gathering information on the number of different foreign countries listed as the first inventing country for each non-US *prior art* patent. Information was averaged across all patents owned by the firms. For example, if there were five prior art of international/foreign origin out of a total of eight listed prior art for a patent, then information extraction involved noting that among these five, four were from Japan and one was from Italy. In this case, foreign knowledge was transferred or sourced from two different foreign countries.

R&D resources (R&D) was measured using a 2-year lag variable for R&D spending. The 2-year lag was considered appropriate based on approximate information on the average time required to file a patent from the time of its inception. *Past experience with international knowledge transfer* (PKnow_Exp) was measured as the cumulative international/foreign prior art sourced by a firm divided by the cumulative patents granted to the firm up to a year prior to the year under consideration. This time period was limited to one year, because discoveries in the pharmaceutical industry do not necessarily follow predictable patterns. *Absolute quality of international knowledge* (Abs_Kn_Qual) was measured as the average number of citations received by international/foreign prior art. *Relative quality of internationalknowledge*(Rel_Kn_Qual)wasmeasured by examining the difference between the average number of citations received by international/foreign prior art and the average number of citations received by local/domestic prior art.

Control variables

Control variables were included in the analysis to partial out the effect of the firm's past innovative capabilities prior to 1991. Doing so, we could better single out the effect of the above independent variables' impact on the firm's innovative performance in the 1990s. Data for the period prior to 1991 were used in constructing control variables such as *Past innovative capacity* (PInnov_Cap) and *Past experience with internationally dispersed knowledge* (PKnow_Div), which required longitudinal as well as cumulative information.

Past innovative capacity (PInnov_Cap) was measured as the cumulative citations received by a firm

(up to a year prior to the year under consideration) divided by the cumulative number of patents granted to the firm prior to the year in consideration. *Past experience with internationally dispersed knowledge* (PKnow_Div: i.e., the qualitative frequency of experience with internationally diverse and dispersed knowledge) was measured as the cumulative number of foreign countries from which a firm transferred knowledge divided by the cumulative number of patents granted to the firm up to a year prior to the year under consideration. *Firm effects* were represented by 52 dummy variables for 53 firms (i.e., 53-1=52 degrees of freedom). The value of 1 represented a firm's presence and 0 its absence from the data point in the pooled data. Zambon was the residual firm in the dummy variable classification scheme that was used. Taking into consideration the innovation cycles of an industry and strategic filing of patents by pharmaceutical firms, *year effects* were introduced. The dummy variables for the years between 1991 and 1997 took the value lor 0 corresponding to relevant data points in the pool data. The year 1998 was the residual year in the dummy variable classification scheme.

Analysis and results

The conceptual framework (see Figure 1) was tested using a pooled cross-section/time-series regression method. Data on 53 sample firms for the period 1991-1995 were analyzed using a pooled cross-section/time-series regression method (n=53 firms x 5 years=265). A major strength of pooling techniques is that they enable an examination of variations among cross-sectional units simultaneously with variations within individual units over time (Bergh, 1993). This allows the investigation of more complex and realistic models than could be achieved by using either cross-section or time-series methods alone (Bergh, 1993). Further, pooling increases the degrees of freedom, because more observations are available as a result of combining cross-section and time-series data. Finally, this study design can capture the longitudinal shift in the pharmaceutical firms' innovative performance *relative to* their own past over time. The conceptual framework was tested using a pooled cross-section/time-series regression method. A major strength of pooling techniques is that they enable an examination of variations among cross-sectional units simultaneously with variations within individual units over time (Bergh, 1993).

In order to reduce potential multicollinearity among independent variables, we followed recommendations of Cronbach (1987) and Swamidass and Kotabe (1993) and standardized and mean-centered all the variables. Then we checked variance inflation factors (VIF) in the regression to monitor any potential problems of multicollinearity. VIF results suggested that multicollinearity was not a problem.

Tables 1-3 show the descriptive statistics, correlation matrix, parameter estimates and test statistics

Table 1 Descriptive statistics on the full sample (*n*=265) for testing Hypotheses 1–3

Variable	*Mean*	*St. dev.*	*Minimum*	*Maximum*
Dependent variable				
Innovative performance (Innov_Perf)	2.09	2.62	0	15.61
Independent variables				
International knowledge transfer (Int_Know)	0.24	0.18	0	1.00
Knowledge complexity (Know_Cpx)	1.39	0.77	0	4.50
International knowledge dispersion (Know_Disp)	1.12	0.77	0	4.00
Control variables: Set A				
Past innovative capacity (PInnov_Cap)	5.00	3.83	0	26.18
Past experience with international knowledge diversity (PKnow_Div)	1.23	0.42	0	3.00
Control variables: Set B (determinants of Int_Know)				
Past experience with international knowledge transfer (PKnow_Exp)	0.35	0.14	0	0.79
Absolute quality of international knowledge (Abs_Kn_Qual)	15.05	11.44	0	55.74
Relative quality of international knowledge (Rel_Kn_Qual)	−7.90	23.38	−282.7	53.20

Note: R&D resources are not included in model owing to missing data.

Table 2 Correlation matrix on the full sample (n=265) for testing Hypotheses 1–3

Variable name	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1. Innovative performance	—								
2. International knowledge transfer	0.25***	—							
3. Absolute quality of international knowledge	−0.49***	0.47***	—						
4. Relative quality of international knowledge	−0.10	−0.01	−0.05	—					
5. International knowledge dispersion	0.21***	0.56***	0.50***	−0.02	—				
6. Knowledge complexity	0.45***	0.44***	0.45	−0.14	0.52	—			
7. Past innovative capacity	0.59***	0.06	0.36***	−0.15	0.21	0.31***	—		
8. Past experience with international knowledge transfer	−0.22***	−0.11*	−0.32***	0.13**	−0.33***	−0.33***	−0.45***	—	
9. Past experience with international knowledge diversity 0.05	0.03	0.16***	−0.03	0.11*	0.05	0.10*	0.04	—	

*$P<0.10$, **$P<0.05$, ***$P<0.01$.
Note: R&D resources are not included in model owing to missing data.

Table 3 Effect of international knowledge transfer on firm innovative performance: parameter estimates on the full sample (n=265) for testing Hypotheses 1–3

Variable name	*Beta coefficient (t-statistic)*
Intercept	−2.06 (−2.04)**
Independent variables	
International knowledge transfer (Int_Know)	4.86 (2.38)***
Squared international knowledge transfer (Int_Know_SQ)	−5.38 (−2.25)**
Knowledge complexity (Know_Cpx)	0.32 (1.60)
International knowledge dispersion (Know_Disp)	−0.81 (−4.40)***
Control variables: Set A	
Past innovative capacity (PInnov_Cap)	0.29 (3.06)***
Past experience with international knowledge diversity (PKnow_Div)	−1.66 (−3.93)***
Control variables: Set B	
Past experience with international knowledge transfer (PKnow_Exp)	4.99 (3.18)***
Absolute quality of international knowledge (Abs_Kn_Qual)	0.067 (4.26)***
Relative quality of international knowledge (Rel_Kn_Qual)	0.003 (0.81)
R^2	0.70

Dependent variable: Innovative performance.
t-statistics in parentheses; two-tailed tests.
**$P<0.05$, ***$P<0.01$.
Note: We also controlled for firm and year effects using dummy variables not shown here.

for testing the effect of international knowledge transfer on innovative performance (Hypothesis 1) along with the effects of the firm's ability to process knowledge complexity (Hypothesis 2) and international knowledge dispersion (Hypothesis 3) on innovative performance for the full model sample («=265). In both standardized and non-standardized cases, adding the squared term for the international knowledge transfer variable (Int_Know_SQ) significantly increased the proportion of variance explained. The model specification is shown in Eq. (1) below. In Eq. (1), the control variables are in italic. We included two sets of controls in our equation. First, we assumed that organizations with greater past innovative capacity and past experience with internationally dispersed knowledge are more likely to have greater innovative performance. Second, since the decision to engage in international knowledge transfer is affected by important determinant variables (Hypotheses 4-7), we assumed that that it was important to include these variables in Eq. (1)

as controls to ensure that the effects of the independent variables were not spurious.

$$\begin{aligned}\text{Innov\_Perf} = &\beta_1(\text{Int\_Know}) + \beta_2(\text{Int\_KnSQ}) \\ &+ \beta_3(\text{Know\_Cpx}) + \beta_4(\text{Know\_Disp}) \\ &+ \beta_5(\text{PInnov\_Cap}) + \beta_6(\text{PKnow\_Exp}) \\ &+ \beta_7(\text{PKnow\_Div}) + \beta_8(\text{Abs\_Kn\_Qual}) \\ &+ \beta_9(\text{Rel\_Kn\_Qual})\end{aligned} \tag{1}$$

The central argument in our research is presented in Hypothesis 1, which states that the relationship between international knowledge transfer and innovative performance will be nonlinear, with innovative performance increasing up to an optimal level, beyond which higher levels of international knowledge transfer lead to a decline in innovative performance. Results support this hypothesis. Table 3 shows a significant positive regression coefficient (j8=4.86, t=2.38) between the dependent variable innovative performance (Innov_Perf) and the first-order term of the independent variable international knowledge transfer (Int_Know). In addition, the evidence confirms the hypothesized inverted U-shaped or curvilinear relationship between international knowledge and innovative performance, as indicated by the significant negative regression coefficient (/?=—5.38, t=—2.25) between the dependent variable innovative performance (Innov_Perf) and the second-order term of the independent variable international knowledge transfer squared (Int_Know_SQ). The point of inflection, where the costs of transferring or sourcing international knowledge exceed its benefits, can be computed by taking the partial derivative of regression Eq. (1), listed above, with respect to the international knowledge transfer variable (Int_Know) as follows:

$$\frac{\partial(\text{Innov\_Perf})}{\partial(\text{Int\_Know})} = \beta_1 - 2\beta_2(\text{Int\_Know}) \tag{2}$$

Based on this procedure, the inflection point was determined to be at 0.45 level of international knowledge content (Int_Know). In other words, innovative performance (Innov_Perf) as measured by citations per patent begins to decline when the international knowledge content exceeds 45% of total cited *prior art* knowledge. Moreover, the signs for the international knowledge transfer (Int_Know) coefficient and the calculation of the inflection point above suggest that these moderate levels of outsourcing international knowledge are beneficial in terms of enhancing innovation. At higher levels beyond this inflection point, however, the opposite effect is apparent, as indicated by the corresponding signs for the regression coefficient of the squared international knowledge transfer term (Int_Know_SQ).

Hypothesis 2 states that firms that process knowledge complexity have better innovative performance than those that process less. Surprisingly, Table 3 shows a non-significant knowledge complexity (Know_Cpx) coefficient (0=0.32, *t=l.60).* Therefore this hypothesis is not supported, although the coefficient has the expected positive sign, and the correlation coefficient between innovative performance (Innov_Perf) and knowledge complexity (Know_Cpx) is positive and significant at the P<0.01 level (see Table 2). Hypothesis 3 states that firms transferring knowledge from fewer international locations have better innovative performance than those that transfer knowledge from a larger number of international locations. Among other independent variables in the model, Table 3 shows that the coefficient for the international knowledge dispersion variable (Know_Disp) has a statistically significant negative coefficient (0=-0.81, t=4.4), indicating support for this hypothesis.

Our international knowledge transfer model included several control variables. Table 3 contains the regression coefficients for these control variables. It should be noted that two sets of control variables were included in our analysis. Control variable set number 1 included the following control variables to partial out the potential effect of the firm's past innovative capabilities: *Past innovative capacity* (PInnov_Cap) and *Past experience with internationally dispersed knowledge* (PKnow_-Div). The statistically significant beta coefficient (0=-1.66, t=—3.93) for *Past experience with international knowledge diversity* (PKnow_Div) offers further support for our Hypothesis 3 and strengthens the argument in the theory section that a firm's innovative performance will increase when it develops strong transferring or sourcing relationships with fewer international locations. The parameter estimates also show that there is a statistically significant positive relationship between past innovative capacity (PInnov_Cap) (0=0.29, t=3.06) and innovative performance (Innov_Perf).

Control variable set number 2 included the following 'determinant' variables, which are proposed later in the analysis to affect international knowledge sourcing: *Past experience with international knowledge* (PKnow_Exp), *Relative quality of international knowledge* (Rel_Kn_Qual), and *Absolute quality*

of international knowledge (Abs_Kn_Qual). It should be noted that *R&D resources* (R&D) was not included as a control in this part of the analysis owing to a large number of missing R&D data. Results indicate that there is a statistically significant positive relationship with past experience with international knowledge transfer (PKnow_Exp) and innovative performance (Innov_Perf) (β=4.99, t=3.18). Table 3 further shows that, while relative quality of international knowledge (Rel_Kn_Qual) (β=0.003, t=0.81) was non-significant, absolute quality of international knowledge (Abs_Kn_Qual) was statistically significant (β=0.067, t=4.26) for innovative performance (Innov_Perf). In addition, we also controlled for firm effects and year effects using dummy variables (results not shown in tables). As expected, including these control variables resulted in a significant increase in our R^2 term.

In the next step of our analysis, we tested the relationship between international knowledge transfer and its determinants, as stated in Hypotheses 4–7. Note that because R&D spending data were unavailable for many firms in our initial sample, we had to test these hypotheses using a reduced sample of 22 firms in the US pharmaceutical industry. The descriptive statistics, correlation matrix, parameter estimates and test statistics for the analysis of our reduced sample of 22 firms (n=22 firms × 5 years=110) are shown in Tables 4–6. The complete model specification is shown in Eq. (3) below. In Eq. (3), the control variable is in italic. Again, we standardized and mean-centered the variables. We then followed the suggestions from Swamidass and Kotabe (1993), by using stepwise regression in our subsequent analysis. This procedure allowed us to monitor any potential problems of multicollinearity. Our variance inflation factor (VIF) analysis revealed that multicollinearity was not a problem.

$$\begin{aligned}\text{Int\_Know} = &\beta_1(\text{R\&D}) + \beta_2(\text{PKnow\_Exp}) \\ &+ \beta_3(\text{Rel\_Kn\_Qual}) \\ &+ \beta_4(\text{Abs\_Kn\_Qual}) \\ &+ \beta_9(\text{Know\_Disp})\end{aligned} \tag{3}$$

Hypothesis 4 states that firms with greater R&D resources (R&D) will source international knowledge to a greater extent. Using a 2-year lag variable for R&D resources produced highly significant results, as shown in Table 6 for all models contain-

Table 4 Descriptive statistics on the reduced sample (n=110) for testing Hypotheses 4–7

Variable	*Mean*	*St. dev.*	*Minimum*	*Maximum*
Dependent variable				
International knowledge transfer (Int_Know)	36.51	13.25	10.26	80.00
Independent variables				
R&D resources (R&D)	5.56	4.64	0.04	16.68
Past experience with international knowledge transfer (PKnow_Exp)	29.68	7.56	14.30	47.86
Relative quality of international knowledge (Rel_Kn_Qual)	−13.63	32.20	−282.70	28.13
Absolute quality of international knowledge (Abs_Kn_Qual)	18.88	10.23	0	45.84
Control variable				
Knowledge dispersion (Know_Disp)	1.47	0.41	0	2.57

Table 5 Correlation matrix on the reduced sample (n=110) for testing Hypotheses 4–7

Variable name	*1*	*2*	*3*	*4*	*5*	*6*
1. International knowledge	—					
2. R&D resources	0.35***	—				
3. Absolute quality of international knowledge	−0.44***	−0.08	—			
4. Relative quality of international knowledge	0.14	−0.13	−0.03	—		
5. Past experience with international knowledge transfer	0.48***	0.45***	−0.32***	0.06	—	
6. Knowledge dispersion	0.26***	0.14	−0.03	0.11	0.10	—

t-statistics in parentheses; two-tailed tests.
***$P<0.01$.

Table 6 Effect of determinant variables on international knowledge transfer: parameter estimates on the reduced sample (n=110) for testing Hypotheses 4–7

Variable name	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*
Intercept	30.80 (16.6)***	41.60 (15.6)***	42.00 (15.9)***	28.50 (5.2)***	20.10 (3.1)***
Independent variables					
R&D	1.01 (3.9)***	0.92 (3.9)***	0.99 (4.3)***	0.66 (2.6)***	0.58 (2.3)**
Abs_Kn_Qual	−0.54 (−5.1)***	−0.53 (−5.1)***	−0.43 (−4.1)***	−0.43 (−4.2)***	
Rel_Kn_Qual	0.07 (2.2)**	0.06 (1.8)*	0.05 (1.5)		
PKnow_Exp	0.45 (2.8)***	0.44 (2.8)***			
Control variable					
Know_Disp	5.90 (2.4)**				
R^2	0.12	0.30	0.33	0.37	0.41

Dependent variable: International knowledge transfer.
t-statistics in parentheses; two-tailed tests.
*$P<0.10$, **$P<0.05$, ***$P<0.01$.
Note: We also controlled for firm and year effects using dummy variables not shown here.

ing the variable R&D resources. The two-year lag was considered appropriate, based on approximate information on the average time required to file a patent from the time of its inception. In the complete model (i.e., Model 5: see Table 6) the beta coefficient (β=0.58, t=2.3) for the *R&D resource* variable (R&D) supports our hypothesis. The beta coefficient in model 5 for the variable *Past experience with international knowledge* (PKnow_Exp) transfer is 0.44 (t=2.8), indicating support for Hypothesis 5, which states that firms with greater past experience with transferring international knowledge will transfer a greater extent of international knowledge in the current year.

Hypothesis 6 states that the higher the quality of international knowledge relative to local knowledge, the greater will be the extent of international knowledge used by a firm. The parameter estimates offer only limited support for this hypothesis, since the beta coefficients for relative quality of international knowledge (Rel_Kn_Qual) in models 3 and 4 were significant only at the 0.10 level, and were not significant for model 5, which controlled for international knowledge dispersion (Know_Disp).

In addition, Hypothesis 7 states that the higher the absolute quality of international knowledge (Abs_Kn_Qual), the less is the extent of international knowledge obtained by the firm. The negative beta coefficient in model 5 for international knowledge quality (β=−0.43, t=−4.20) offers strong support for this hypothesis. The coefficients for models 2, 3 and 4 are also statistically significant. These results suggest that there are theoretical rationales for examining the effects of two types of international knowledge acquisition strategy: knowledge quantity strategy and knowledge quality strategy. Examining these effects shows that absolute and relative international knowledge quality have difference outcomes on the firm's decision to transfer knowledge from cross-national locations.

We included other control variables in the testing of our model regarding the determinants of international knowledge transfer. Model 5 in Table 6 contains a statistically significant beta coefficient (β=5.90, t=2.4) for the variable *International knowledge dispersion* (Know_Disp). Following the same rationale for the international knowledge transfer/innovative performance framework, we controlled for firm effects and year effects using dummy variables (results not shown in tables).

In the next section, we will discuss the potential theoretical and managerial implications of our findings. We will also offer potential avenues for future research in the area of international knowledge transfer.

Discussion and implications

In general, the results support the central hypothesis of our research that transferring international knowledge largely benefits the innovative performance in an inverted U-shaped relationship. In addition, our findings provide a plausible explanation for the internationalization of the R&D function, and weaken the traditional argument for home-centered R&D. However, while the transferring or sourcing of knowledge largely encourages innovation, too much transferring without careful

consideration of the optimality at work may reduce the benefits of learning from diverse knowledge resources. The measure of international knowledge introduced in this study proved to be a powerful predictor of the average international knowledge transferred by pharmaceutical firms in the US between the years 1990 and 1998: average knowledge transfer was approximately 24% (see Table 1). This pattern of distribution shows that most firms did not exceed the 45% level (i.e., our calculated inflection point) at which innovative performance is maximized, and thus were operating below the optimum point at which the negative consequences of international knowledge are not of concern.

While it may be advantageous to continually invest in high-quality knowledge resources, our model indicates that, over time, there may be a greater risk of subsequent reduction in the quality of these resources if a firm continues to use higher levels of international knowledge, owing to the higher costs of managing such excessive diversity. Thus, given that the transferring of high-quality knowledge requires greater in-depth scrutiny and absorptive capabilities, our findings support the idea that firms are more likely to enhance their innovative performance by transferring knowledge from fewer international locations. In other words, firms transferring knowledge from select locations may be able to achieve the necessary focus and amount of internal resources to be able to successfully integrate new knowledge learned from these resources into their innovation process.

The decision to transfer or source international knowledge is consistent with previous research findings that have found that, even though there are positive marginal benefits to transferring or sourcing international knowledge, the internationalization of R&D remains a small but yet growing phenomenon. Our findings suggest that firms transferring international knowledge from abroad take the risk as well as the advantage of being early movers based on their subjective assessment of risks and experience of subsequent benefits involved. The ability to make good assessments is affected by their own experiences with transferring knowledge from overseas. An ethnocentric strategy to keep R&D in the home country may stop firms from achieving their optimum international knowledge position. Similarly, firm reluctance to transfer international knowledge may be due to a need to seek legitimacy within the local knowledge network driven by path-dependent technological trends (Dosi *et al,* 1991). Studies posit that there is a considerable risk that firms, institutions and networks become 'locked in' to the 'old' technologies. Thus the particular features of a firm's absorptive capacity (Cohen and Levinthal, 1990) influence its ability to evaluate and search for new knowledge content. It is therefore important for firms to build a broad technology base that recognizes the benefits from transferring or sourcing new diverse technologies. Additionally, our findings suggest that transferring knowledge from many international disperse locations may increase knowledge complexity beyond acceptable levels for effective communication and coordination (Hitt *et al.,* 1997). Therefore the corresponding prediction of our study is that firms prefer fewer or high-quality knowledge sources to learn from. It is these choices that enable the firm to achieve an acceptable threshold of knowledge complexity.

Our overall findings suggest that the focus on transferring international knowledge and its effect on innovative performance is not only theoretically important, but also offers insights to managers wanting to develop new innovative efforts. In a world in which firms traditionally specialize, co-locate and base their innovation efforts at home, it can be a challenge to encourage firms, especially large ones with proven records of domestic innovation, to transfer international knowledge. Another equally important managerial implication of our study is that our measure of international knowledge transfer proved to be a powerful predictor of the average international knowledge transfer by pharmaceutical firms in the US during the period from 1990 to 1998.[5] In addition, it is hoped that our findings will provide managers with an additional criterion for evaluating the benefits, costs and contingencies when transferring knowledge from international locations. Further, this study addresses some important trade-offs between (1) the qualitative *vs* quantitative aspects of knowledge diversity and (2) the local/domestic *vs* international/foreign knowledge aspects of knowledge. Our empirical findings are particularly useful because they provide additional insights into the optimality of International knowledge transfer at work in a growing environment of increased internationalization of the R&D function. Additionally, from a corporate managerial perspective, the results of our study should help in planning for future innovation centers. Based on our findings, corporate managers of multinational corporations that are transferring or sourcing less than 45% of

their knowledge content from international knowledge resources may want to consider greater interaction among their subsidiaries and other knowledge acquisition arrangements (e.g., joint ventures).

The results of the study also have ramifications for public policymakers. They may even change the perception of investment risk managers, who must consider the risks surrounding foreign direct investment in knowledge-intensive sectors. For instance, based on our findings, knowledge gained from FDI investments may appear to be more lucrative than traditional industrial or capital investments. A growing desirability of such knowledge may induce further growth in global service and financial industries in particular. It is important, however, to note that globalization and, more specifically, the internationalization of the innovation process imply neither a reduction in national differentiation nor a reduced need for public policy. Interestingly, globalization processes can actually intensify the importance of regional differences, making policy action more rather than less important.

Despite the practical implications of our findings, there are limitations in our study. In particular, our study is biased toward large firms in the US pharmaceutical market. Although the results from our sample are strong, we recognize that interpreting them for smaller firms in this industry may be problematic. In our defense, to alleviate some of this bias, we controlled for the fact that larger firms particularly from developed nations, in terms of innovation, tend to have a distinct, innovative edge (Patel and Pavitt, 1991) in terms of economies of scale compared with smaller firms in this industry. For instance, the path to developing new innovations within the global pharmaceutical industry is a very long and expensive process: it can take up to 10-15years and cost an average of $800 million to bring a new product to market, partly because of strict governmental regulations (Tufts Center for the Study of Drug Development, 2006). According to a recent 2006 IMS World Review study, the North American (47%), European (30%) and Japanese (10.7%) markets accounted for nearly 88% of pharmaceutical sales in 2005. The North American market alone accounted for $265.7 billion of the $565.9 billion dollar pharmaceutical sales market in 2005. Much of the continued growth in the pharmaceutical market is anticipated to occur in the US (IMS Global Insights, 2006). Nonetheless, direct cross-validation of this study in samples of medium-sized or small firms in this industry and other industry groups spanning multiple countries or regions (e.g., Europe, Asia.) would be particularly useful in addressing generalizability issues.

Our primary research interest in this study was in examining the innovative effect of international knowledge sources. However, we could not easily pinpoint whether international knowledge originated from internal or external sources. Given the constraint of the data we used, we could not trace the origin of the patent except for its transfer or source location. Nor could we identify specifically from which country/region international knowledge sources originated. Furthermore, owing to complex mergers and acquisitions and alliances in the global pharmaceutical industry over the years, it would have been difficult to define what constituted an internal or external source of knowledge, or which countries/regions the firms operated in. Nevertheless, we could suggest a future study into the effect of knowledge origin (internal or external to the firm) on innovativeness.

In our study, the US patent data chosen in this study were analyzed using a pooled cross-section/time-series regression method. Although this research design allowed us to capture some longitudinal effect of firms' resources on their innovative performance, it could not infer their actual resource allocation over time. By not being able to look into how firms allocated resources for knowledge acquisition (either from internal sources or from external sources), it is possible that there could be a problem with bidirectional causation (i.e., whether good innovative performance causes firms to further transfer knowledge from overseas, or whether firms that outsource knowledge may free up capacity internally to generate more innovative products). That said, to increase the generalizability of our present findings, future research should address the issue of resource allocations and their effect on innovative performance.

Finally, it is possible that this study's present research measures could be improved. In particular, our measure of international knowledge dispersion was developed by gathering information on the number of different foreign countries listed as the first inventing country for each non-US *prior art* patent. Critics could argue that this measure does not fully capture cross-cultural dispersion or even technological capability dispersion. In our defense, we argue that our international knowledge dispersion variable was an appropriate measure of diversity for our single-industry study. In the pharmaceutical industry, the development of

patents is heavily influenced by cross-cultural knowledge. By utilizing this measure, we were able to capture the amount of dispersion complexity implicit in international knowledge transfer.

In conclusion, the assumption in our model has been that knowledge from a particular national location embodies or reflects in some form its national culture with characteristic mental models. The findings of this study support the notion that firms can proactively combine and re-combine knowledge into significantly enhanced products and production processes by recognizing the incentives to disperse research capabilities to the most attractive locations (Zander, 1997; Porter and Stem, 2001). In particular, we proposed that the optimal relationship between transferring or sourcing international knowledge and innovative firm performance is likely to vary over time and become more or less valuable depending on the level of dependence on foreign technology. Our study found that the net result of transferring a very high level of international knowledge is not necessarily advantageous. Thus, in order to promote better innovative performance, effective managers need to pay closer attention to how they source cross-national knowledge. More specifically, we found that the extent of dispersion in the national origins of knowledge plays a significant role in affecting the innovative returns to transferring or sourcing international knowledge.

Dedication

This work is dedicated to KK, who passed away while assisting us in the course of this manuscript development.

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Notes

Performance slips because members miscode performance situations. Habitual routines reduce the likelihood of innovative performance processes. A group can get into habitual patterns of behavior by importing those patterns, by creating them early in its life, or by gradually evolving them over time. When identifying the conditions under which a group will break out of a habitual routine, three factors are relevant: (1) the impetus for change; (2) the timing of the possible change and (3) the tenacity of the routine itself (Gersick and Hackman, 1990).

[2]Although published patents are, by definition, a depository of explicit knowledge, organizational knowledge is created through a social dynamic and continuous dialogue/process between a range of tacit and explicit components (Nonaka, 1991). While there are certainly tacit components associated with the patents, implicit/tacit costs are also assumed during the learning and knowledge transfer. Some of these costs include: (1) efforts by qualified researchers to read between the explicit lines of the published patent to produce a practice/process that delivers identical results; and (2) the opportunity costs of committing resources in the direction of research that a particular patent takes. According to Roberts (1999), there are some tacit components associated with patents that cannot be detached from their human and social contexts. We argue that patents are an intermediate form of knowledge and are expected to vary in their degree of codifiability and complexity (Kogut and Zander, 1993).

[3]By law, the patent applicant is obligated to list all 'prior art'. Patent applicants must therefore go through a rigorous process of providing the patent examiner with a list of all relevant patent documents (prior art) that aided in the development of their patents. 'Actual referral' refers to the existing patents that were actually used in the development of a new innovation for which the patent applicant is seeking a patent.

[4]Endogenous sunk costs in the form of R&D decisions do play a crucial role in several industries, such as in the global pharmaceutical industry (Matraves, 1999).

[5]We thank an anonymous reviewer for this comment.

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Appendix

Existing literature and nature of research gap

Existing research	*Research gap*
International sourcing by MNEs has been argued as an important strategy for global rationalization in the context of components, subassemblies and finished products (Kotabe and Omura, 1989; Swamidass and Kotabe, 1993; Kotabe, 1998).	The phenomenon of international sourcing is largely unexplored in the emerging area of *firm knowledge.*
The significance of the innovative role of multinational subsidiaries has increased in recent years with R&D internationalization (Choshal and Bartlett, 1988; Hakanson and Zander, 1988; Bartlett and Choshal, 1989, 1998; Cheng and Bolon, 1993; Chiesa and Manzini, 1996), and the MNE has been conceptually portrayed as an integrator of knowledge within its umbrella of ownership and control. In the international business stream, scholars have argued both for and against any benefits resulting from such integration of knowledge from decentralized knowledge bases.	There are few theoretical and empirical studies that examine the implications of R&D internationalization for innovative performance. A substantiation of the theoretical debate on knowledge integration and its value to a firm is largely unexplored. This research posits that novel concepts germinate from synthesis of diverse knowledge from different national sites, and tests the hypothesis empirically.
IB literature discusses various sources of locational advantage: • Knowledge is sourced from the host country locations for reasons such as to exploit cultural or idiosyncratic aspects, to access user-oriented information, or to be locally responsive • Knowledge is sourced from the parent country location to utilize and seek rents from existing proprietary resources, to seek parent-owned technology-oriented information, and to exploit locational advantage of the parent country.	The question of how these different sources of locational advantage from different locations combine within an MNE has not been addressed. Is there a possible tradeoff between the local and internationally sourced knowledge that can maximize innovation?
There is ongoing theoretical debate between 'strategic-positioning' and 'resource-based' schools.	This study resolves this debate and strengthens the argument that a multinational firm enhances its knowledge resource by strategically positioning its knowledge base to gain competitive advantage.
There is discussion on measurability and value of knowledge. Patent count is used as a measure of innovative activity and output.	The quality aspect of innovative output is ignored (Kotabe, 1992). This study uses a patent-based measure of innovation and improves the measurement by including industry cross-referencing as a measure of patent quality.
Joint authorship has been used as a measure of knowledge-sharing in scientific research.	*Prior art* citations in patents have been used in this study as a measure of knowledge flow.

About the authors

Masaaki Kotabe holds the Washburn Chair Professorship in International Business and Marketing, and is the director of research at the Institute of Global Management Studies at the Fox School of Business and Management, Temple University. His research interest includes international marketing, global sourcing strategies, international alliances, and issues related to product and process innovations.

Denise Dunlap-Hinkler earned her PhD in Global and Strategic Management at Temple University's Fox School of Business and Management. She is an Assistant Professor at the School of Business Administration at Widener University. Her primary research interests include international business theory and practice and knowledge management strategies. Her current research focuses on how international transfer/sourcing issues affect product and process innovations.

Ronaldo Parente earned his PhD in Global and Strategic Management at Temple University's Fox School of Business and Management. He is an Assistant Professor of Management at Rutgers University. His research interest includes global sourcing strategies, modularization, international strategy, supply chain management, . and issues related to new product development.

Harsh A. Mishra earned his PhD in Global and Strategic Management at Temple University's Fox School of Business and Management. He is an Assistant Professor of International Business at the State University of New York-New Paltz. His research interests include cross-national knowledge sourcing and firm innovation, emerging issues on ethics and environmental sustainability in global business, international patent environment, and value-chain configuration management by multinational corporations.

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