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KNOWLEDGE RELATEDNESS AND THE PERFORMANCE OF MULTIBUSINESS FIRMS

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This study examines corporate performance effects of cross-business knowledge synergies in multibusiness firms. It synthesizes the resource-based view of diversification and the economic theory of complementarities to conceptualize cross-business knowledge synergies in terms of the relatedness and the complementarity of knowledge resources across business units of the multibusiness firm. The study hypothesizes that corporate performance is improved when the firm simultaneously exploits a complementary set of related knowledge resources across its business units. In a sample of 303 multibusiness firms, the study finds that synergies arising from product knowledge relatedness, customer knowledge relatedness, or managerial knowledge relatedness do not improve corporate performance on their own. Synergies arising from the complementarity of the three types of knowledge relatedness significantly improve both market-based and accounting-based performance of the multibusiness corporation. Copyright © 2004 John Wiley & Sons, Ltd.

The concept of cross-business synergy is central to the performance of multibusiness firms with diverse business portfolios (Goold and Luchs, 1993). Despite some inconsistent findings, the overall conclusion of nearly four decades of diversification research is that firms whose businesses are resource related achieve superior value whereas firms whose businesses do not share any resources—except maybe financial ones—destroy value (Rumelt, 1974; Hoskisson and Hitt, 1990; Palich, Cardinal, and Miller, 2000; Ramanujam and Varadarajan, 1989). Resource relatedness among business units is assumed to be a source of cross-business synergy that improves the corporate value of the firm (Chatterjee and Wernerfelt, 1991; Farjoun, 1994; Markides and Williamson, 1994; Robins and Wiersema, 1995). Despite the centrality of the concept of 'synergy' in diversification research, existing relatedness constructs and measures intended to capture the underlying resource-based synergies of multibusiness firms are subject to several theoretical and methodological weaknesses.

Theoretically, existing relatedness constructs focus on cross-business synergies arising from the relatedness of certain functional resources: e.g., product relatedness (Rumelt, 1974), manufacturing relatedness (John and Harrison, 1999), technological relatedness (Robins and Wiersema, 1995; Silverman, 1999), R&D relatedness (Chatterjee and Wernerfelt, 1991), marketing relatedness (Capron and Hulland, 1999), advertising relatedness (Chatterjee and Wernerfelt, 1991), managerial relatedness (Ilinitch and Zeithaml, 1995; Prahalad and Bettis, 1986), and human resource relatedness

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(Farjoun, 1994). The manifestations of resource relatedness in multiple functional domains indicate that firms may be seeking to exploit cross-business synergies in multiple functional resources simultaneously. Treating individual dimensions of cross-business synergies as independent and assessing their performance effects separately may lead to inconsistent results and preclude conclusions about the performance effects of cross-business synergies. Further, studies focusing solely on resource relatedness do not recognize that synergies can also arise from different, but complementary resources (Milgrom and Roberts, 1990, 1995; Harrison *et al*., 2001), and that such complementarities are the basis for distinctive corporate strategy (Porter, 1996).

Methodologically, there is limited correspondence between resource-based theory and most operational measures of resource relatedness (Farjoun, 1994; Markides and Williamson, 1994; Robins and Wiersema, 1995). Direct measurement of the relatedness of a firm's strategic resources is difficult at the firm level. Hence, researchers resort to indirect measurements and approximations that rely on the resource similarities of industries and the industry participation profiles of firms. The indirect measures have been criticized for diverging from the direct measures of resource relatedness (Nayyar, 1992), exaggerating firms' resource relatedness (Markides and Williamson, 1994) and capturing relatedness of tangible resources rather than the relatedness of more valuable intangible resources such as knowledge (Davis and Duhaime, 1992). In recent years, researchers have substantially improved indirect measurement of a firm's knowledge relatedness by using measures of interindustry technology flows (Robins and Wiersema, 1995) and occupational profiles (Farjoun, 1994). Measuring knowledge relatedness more directly at the firm level may further increase the correspondence between resource-based views of related diversification and operational measures of relatedness. Such a correspondence would also increase the validity of results and consequent implications for management.

Further, most studies focus on the measurement of a firm's relatedness strategy (Hill, Hitt, and Hoskisson, 1992), which captures *potential relatedness*—that is, whether a firm is positioned across business segments that have a potential to share common resources with each other. Yet the relatedness hypothesis is about the performance effects of actual, not potential, relatedness (Nayyar, 1992). Although many studies assume that potential relatedness will automatically translate into *actual relatedness* and lead to the expected performance improvements, in practice implementation difficulties prevent many firms from realizing the potential synergies among their business segments (Nayyar, 1992). When studies use potential relatedness as a proxy for actual relatedness, interpreting their results is difficult: if business units do not share resources and, as a result, the firm performs poorly, is the poor performance due to the unrelatedness of the businesses or the firm's inability to share the related resources?

Finally, existing relatedness measures have been developed and tested almost exclusively in the manufacturing sectors. Hence, their applicability to service sectors has been questioned (Gassenheimer and Keep, 1998; Nayyar, 1992). For example, technological relatedness was operationalized using patent data in manufacturing sectors (Robins and Wiersema, 1995; Silverman, 1999) but the patent mechanism is rarely used in service sectors. Further, patenting is not relevant for protecting some strategic knowledge resources of service firms such as customer knowledge. Although the human resource relatedness measure developed by Farjoun (1994) is potentially applicable in service sectors too, Farjoun (1994) applied it only in the manufacturing sectors. Given the significance of service sectors, and the presence of both service and manufacturing businesses in business portfolios of many diversified firms, it is important to develop measures that capture knowledge relatedness of both service and manufacturing businesses.

This study develops and validates a new conceptualization and measurement of cross-business knowledge synergies that address some of the weaknesses identified above. Theoretically, it synthesizes the resource-based views (RBV) of diversification and the economic theory of complementarities to conceptualize cross-business knowledge synergies of a multibusiness firm in terms of the relatedness and complementarity of knowledge resources used by the business units of the firm. It construes cross-business knowledge synergy as a second-order construct. The first level of the construct captures cross-business synergies arising from the relatedness of knowledge resources. In particular, it focuses on product knowledge relatedness, customer knowledge relatedness, and

managerial knowledge relatedness. The second level of the construct captures additional synergies arising from the complementarity of the three types of knowledge relatedness. The study explains why the synergies arising from the three types of knowledge relatedness are necessary but not sufficient and why their coexistence and complementarity are also required to increase corporate performance of multibusiness firms.

Methodologically, this study increases the correspondence between RBV-based conceptualization of relatedness and operational measures of relatedness by measuring knowledge relatedness directly at the firm level. It avoids the confounding between relatedness strategy and implementation capability of the firm by developing a new measurement scheme that captures actual relatedness rather than potential relatedness of a firm's businesses. It ensures that the new measurement instruments are applicable in both service and manufacturing sectors by validating them with a sample of service and manufacturing firms. With these theoretical and methodological advances, the study finds that cross-business knowledge synergies predict objective measures of accounting-based (ROA, ROE) and market-based firm performance (Tobin's q) after controlling for three established measures of relatedness, and other firm- and industry-level factors.

The paper is organized as follows. We start with a discussion of the concept of synergy and sources of synergy and integrate the resource-based view (RBV) of diversification and the economic theory of complementarities to propose 'resource relatedness' and 'resource complementarity' as distinctive sources of cross-business synergy in multibusiness firms. We review the diversification literature and identify product, customer, and managerial knowledge as the most strategic knowledge resources of the firm. We then argue that related product knowledge, related customer knowledge, and related managerial knowledge can create distinct synergies. Next, we explain that complementarities among the three types of knowledge relatedness could create additional synergies. We discuss performance effects of the synergies arising from the relatedness of knowledge resources and the complementarity of different types of knowledge relatedness. We then present an empirical study designed to validate the knowledge synergy construct and test its proposed effects on corporate performance. We conclude by discussing findings, their implications for research and practice, limitations, and potential avenues for future extensions.

THEORETICAL FOUNDATIONS

A key proposition of the strategic management literature is that the overall value of a multibusiness firm exceeds the sum of individual values of its businesses when there are synergies among the businesses (Goold and Luchs, 1993). Super-additive value synergies between businesses (a) and (b) make their joint value greater than the sum of their standalone values: i.e., Value (a, b) > Value (a) + Value (b) (Davis and Thomas, 1993). The term 'synergy' has also been used synonymously with the term 'economies of scope,' and conceptualized in terms of the sub-additivity of production costs. When businesses (a) and (b) share some common factors of production, they achieve 'synergies' or 'economies of scope' because their joint production costs are less than the sum of their stand-alone production costs: i.e., Cost (a, b) < Cost (a) + Cost (b) (Teece, 1982).[1]

These conceptualizations are problematic for examining the direct link between synergy and firm performance because they define synergy in terms of outcomes: i.e., if there is synergy, it must be observed in outcomes in the form of super-additive value or sub-additive costs. When both synergy and performance are defined in outcome terms, the relationship between synergy and firm performance becomes tautological. One approach to avoid the tautology problem is to focus on sources of synergy rather than synergy per se (Davis and Thomas, 1993).

Sources of synergy in multibusiness firms

The most widely studied source of synergy in multibusiness firms is the 'resource relatedness' of businesses. Resource relatedness refers to the 'presence of similar activities and shared resources' across business units of the firm (Davis and Thomas, 1993). Researchers building on the resource-based view (RBV) of diversification posit that the sharing of strategic resources among

[1] Economies of scope are not to be confused with economies of scale, which refer to cost savings due to volume of production within a particular business.

business units creates cross-business 'resource-based synergies,' which in turn improve the overall value of the corporation (Farjoun, 1994; Markides and Williamson, 1994; Robins and Wiersema, 1995). They examine the link between resource relatedness and firm performance to understand if the synergies arising from the relatedness of resources make any difference in firm value. This approach eliminates the tautology problem.

Resource sharing indicates that the business units are using common factors of production and achieving economies of scope: i.e., their joint production costs are less than the sum of their stand-alone production costs. Hence, the main type of synergy captured by 'resource relatedness' is sub-additivity in production costs. The value of a multibusiness firm is a function of both sub-additive costs and super-additive values of the underlying resource combinations. The 'resource relatedness' construct does not adequately capture the super-additive value of the resource combinations.

The economic theory of complementarities informs us about the super-additive value of resource combinations. It defines a set of resources as complementary when doing more of any one of them increases the returns to doing more of the others (Milgrom and Roberts, 1995). Complementary resources are not identical, but they are interdependent and mutually supportive. The returns obtained from the joint adoption of complementary resources are greater than the sum of returns obtained from the adoption of individual resources in isolation (Milgrom and Roberts, 1995). Thus, the use of a complementary set of related resources across business units can create additional, super-additive value synergies that are not captured by resource relatedness. The notion that resource complementarity is an important source of synergy in business combinations has been recognized in literature streams on acquisitions and alliances (Harrison *et al*., 2001).

We synthesize the resource-based view (RBV) of diversification and the economic theory of complementarities to argue that both the relatedness and the complementarity of resources can confer synergies. We conceptualize cross-business knowledge synergy of a multibusiness in terms of: (1) synergies arising from the relatedness of knowledge resources across business units; and (2) synergies arising from the use of a complementary set of related knowledge resources across the business units.

Synergies arising from knowledge relatedness

We define knowledge relatedness as '*the extent to which a multibusiness firm uses common knowledge resources across its business units.*' This construct is theoretically grounded in the resource-based view (RBV) of diversification (Farjoun, 1994; Markides and Williamson, 1994; Robins and Wiersema, 1995): resource relatedness, that is, the use of common resources across business units, creates synergies or economies of scope in the form of sub-additive costs across the firm.

Knowledge relatedness of a firm can theoretically be construed in many different dimensions because firms possess different types of knowledge resources (Schulz, 2001). However, it is costly to create and exploit common knowledge resources across multiple business units (Hill and Hoskisson, 1987; Nayyar, 1993a). Unless benefits exceed costs, achieving knowledge relatedness may not lead to the expected performance payoffs (Gupta and Govindarajan, 2000). Therefore, in specifying the dimensionality of knowledge relatedness, we focus on knowledge resources whose relatedness across business units is likely to create significant economies of scope and have a positive effect on corporate performance.

Knowledge resources of a firm can be categorized into tacit and explicit. Tacit knowledge resides in the minds of human resources (Farjoun, 1994). It is costly to articulate and communicate. Explicit knowledge is embedded in product and process technologies (Rumelt, 1974), patents (Robins and Wiersema, 1995), organizational processes, routines, and rules (Nelson and Winter, 1982). It can be expressed and communicated. Creation of economies of scope from knowledge requires the firm to use the same knowledge resources across multiple businesses. In general, tacit knowledge is sticky and costly to transfer (Szulanski, 1996). While human resources can be rotated across business units to facilitate the reuse of tacit knowledge, only a limited number of business units can benefit from the services of a human being at any given time. Hence, tacit knowledge has limited potential to create significant economies of scope in a multibusiness firm. However, explicit knowledge, which is embedded in technologies and organizational processes, can

be used at many business units simultaneously and create significant economies of scope. Hence, we focus on explicit knowledge.

Existing relatedness constructs define three major knowledge domains in which firms seek to exploit synergies. The constructs of product relatedness (St John and Harrison, 1999; Rumelt, 1974), technological relatedness (Robins and Wiersema, 1995), and R&D relatedness (Chatterjee and Wernerfelt, 1991) indicate that knowledge embedded in *products* is an important source of synergy. The constructs of market relatedness (Capron and Hulland, 1999) and advertising relatedness (Chatterjee and Wernerfelt, 1991) indicate that the knowledge of *customers* served in different markets is another important source of synergy. The constructs of dominant managerial logic and managerial relatedness (Ilinitch and Zeithaml, 1995; Prahalad and Bettis, 1986) indicate that firms can also exploit synergies in knowledge residing in *managerial processes and logic*.

Other constructs, such as human resource relatedness (Farjoun, 1994), span two or more of these knowledge domains. For example, since human resources may carry knowledge of products, customers, and managerial processes and logic simultaneously, the human resource relatedness construct captures the relatedness of more than one type of knowledge. To better understand the individual and collective performance effects of the different types of knowledge relatedness, we make conceptual and methodological distinctions among the product, customer, and managerial knowledge resources, and specify product knowledge relatedness, customer knowledge relatedness, and managerial knowledge relatedness as the most important sources of cross-business knowledge synergy in multibusiness firms.

Product knowledge relatedness as a source of synergy

Knowledge is potentially applicable across multiple product markets. But there are few efficient external markets for the exchange of knowledge (Teece, 1980). Thus, the internal market of a multibusiness firm provides opportunities for exploiting similar product knowledge across multiple businesses and creating cross-business synergies (Teece, 1980). Synergies can arise from product knowledge created inside the firm as well as product knowledge acquired from outside through alliances of the firm.

Synergies arising from internally created product knowledge have been the traditional focus of diversification research. Canon's ability to exploit a core set of optical and microelectronic technologies across multiple businesses is a classic example of this logic (Prahalad and Hamel, 1990). Internal product knowledge resides in product and manufacturing platforms (Meyer and Lehnerd, 1997; Robertson and Ulrich, 1998). A product platform is a set of designs, subsystems, interfaces, and components that enables the development of a family of derivative products. Likewise, a manufacturing process platform is a set of process technologies used in the production of a family of products (Meyer and Lehnerd, 1997). Some companies seek to achieve higher product knowledge synergies by developing modular product architectures, flexible manufacturing practices, modules, and module libraries that can be exploited in multiple businesses (Garud, Kumaraswamy, and Langlois, 2003).

Externally acquired product knowledge can also be a source of synergy. In a multibusiness firm, business units form alliances with different suppliers, manufacturers, and R&D partners (Ireland, Hitt, and Vaidyanath, 2002). The product skills and knowledge that each business unit acquires from its own R&D and manufacturing alliances may also be applicable in other business units of the multibusiness firm (Inkpen and Dinur, 1998). To the extent that the firm is able to use the product skills and knowledge acquired from alliance partners of a business unit in other business units as well, the firm enjoys product knowledge synergies.

Synergies arising from the exploitation of common product knowledge across multiple businesses confer both efficiency and effectiveness benefits. When the business units share product designs, subsystems, interfaces, components, and manufacturing processes, the firm can obtain 'asset amortization benefits' from economies of scope (Markides and Williamson, 1994). Reuse of existing product knowledge reduces development, tooling, and manufacturing costs, speeds up new product development, and allows a firm to rapidly address new market opportunities (Meyer and Lehnerd, 1997). New businesses that do not exploit existing product knowledge of the firm suffer from high costs and low margins because new technologies and processes often require major

investments in research, design, engineering, and manufacturing (Nobeoka and Cusumano, 1997). Product knowledge synergies also enhance the effectiveness of a firm. For instance, the effectiveness of 3M is largely attributed to its ability to use common product development and manufacturing process knowledge across its business units. Further, innovations of one business unit may spark ideas for other businesses and lead to 'asset improvement' benefits across the firm (Markides and Williamson, 1994).

Customer knowledge relatedness as a source of synergy

Customer knowledge is also a source of cross-business synergy in multibusiness firms. Customer knowledge refers to the needs, preferences, and buying behaviors of customers—why they purchase specific products and services, which product/service attributes they value, what value they hope to get by using them, and what their businesses are about (Markides and Williamson, 1996; Woodruff, 1997). Firms develop customer knowledge directly through their own interactions with customers (Von Hippel and Katz, 2002) or indirectly through the interactions of their marketing and distribution alliance partners (Glazer, 1991). Since customer knowledge develops over long periods of time through learning relationships with customers (Woodruff, 1997), it is costly to observe and imitate it.

Exchanging knowledge about expressed and latent needs of each other's customers can allow business units of a multibusiness firm to cross-sell their offerings to each other's customers or to develop new products and services. If the customers exhibit similar needs, preferences, and behaviors across different business units of the firm, the firm can reduce its overall marketing and advertising costs by redeploying its general marketing expertise, brands, and sales force among those businesses (Capron and Hulland, 1999). Businesses with dissimilar customer needs and behaviors have minimal opportunity to exploit cross-business customer knowledge synergies. For example, in the banking industry, businesses serving institutional, and individual customer segments have limited similarities. Hence, mixing them has a negative impact on performance (Ramaswamy, 1997).

Managerial knowledge relatedness as a source of synergy

Managerial knowledge by which business units are governed can also be a source of cross-business synergy (Prahalad and Bettis, 1986). Managerial knowledge consists of managerial insights, experiences, and best practices of a firm. Compared to stand-alone businesses, businesses under the governance of a multibusiness firm have a learning scale opportunity in the development and exploitation of managerial knowledge. Businesses face some common managerial challenges regardless of their products and markets. For example, almost all businesses face challenges in the management of risks, investments, and alliances. Fundamental principles of good management are applicable in many different contexts (Koontz, 1969). If some businesses of a multibusiness firm figure out how to effectively deal with some of those managerial challenges, their learning can also be useful to other businesses in the firm. To the extent that the multibusiness firm is able to exploit such learning across multiple business units, it can achieve economies of scope in its managerial knowledge. The managerial knowledge of a multibusiness firm usually resides in its corporate-level managerial processes (Grant, 1988). We focus on three facets of managerial knowledge that are critical for a multibusiness firm: investment management, risk management, and alliance management.

Investment management is critical for the overall value of a multibusiness firm (Rajan and Servaes, 2000). In the absence of common processes that embed the firm's best practices and preferences in investment management, individual businesses tend to manage their investments independently. The lack of coordination can lead to redundancies, duplication of effort in investment management, and hence increased costs across the business units. It can also lead to underinvestment in product and process technologies or marketing and advertising initiatives that could benefit the corporation as a whole (Prahalad and Hamel, 1990). Misallocation of investments negatively impacts the overall value of the firm (Berger and Ofek, 1995).

Risk management is also critical for the overall value of a multibusiness firm (Bettis and Mahajan, 1985). A key objective of a multibusiness firm is to reduce overall risks of its businesses. By forming a portfolio of counter-cyclical businesses, a multibusiness firm can smooth out fluctuations in its

income and minimize negative impacts of external economic conditions. But the formation and maintenance of a counter-cyclical business portfolio require corporate-level coordination. In the absence of coordination, individual businesses may acquire new businesses that do not contribute to the risk minimization objectives of the corporation. By using common risk management principles and processes, the multibusiness firm can coordinate actions of its business units. For example, Hanson Trust PLC is known for its minimization of downside risk. When considering potential acquisitions, a common managerial principle used by Hanson, regardless of the type of business, is to evaluate the size and likelihood of downside risk of the acquisition and its implications for the firm as a whole (Hill and Jones, 1998).

Formation and management of alliances have also become important for multibusiness firms. To acquire complementary resources and capabilities, businesses enter into alliances with external partners (Inkpen, 2001). In a multibusiness firm, each business has numerous alliances with suppliers, manufacturers, distributors, and other business partners. They spend substantial time and effort in identifying alliance partners, determining goals of alliances, negotiating terms, making agreements, choosing appropriate governance structures, building social and relational capital, and managing the alliances (Ireland *et al*., 2002; Inkpen, 2001). Although the specific contents of the alliances are different, managerial challenges entailed in the formation and management of the alliances are similar. To the extent that the multibusiness firm is able to encode its alliance management best practices into some common processes, and exploit those processes across multiple business units, it can exploit economies of scope in its alliance management knowledge. If the individual businesses manage their alliances independently, the firm forgoes such synergies.

Synergies arising from knowledge complementarity

We define knowledge complementarity as the '*the extent to which a multibusiness firm uses a complementary set of common knowledge resources across its business units*.' This construct is derived from the economic theory of complementarities (Milgrom and Roberts, 1995): complementary resources create super-additive value synergies.

In discussing knowledge relatedness, we identified relatedness of product knowledge, relatedness of customer knowledge, and relatedness of managerial knowledge as distinct sources of cross-business knowledge synergy in multibusiness firms. The three types of knowledge relatedness are also complementary to each other. Hence, their coexistence can create additional, super-additive value synergies that are not captured by any one of them in isolation. Conversely, the absence or weakness of one of them can diminish the value of the others too.

R&D knowledge (product knowledge) and marketing and distribution knowledge (customer knowledge) are complementary in business combinations (Harrison *et al*., 2001). The multibusiness firm has an opportunity to use similar product designs, subsystems, interfaces, and components when customers exhibit similar needs, preferences, and purchasing behaviors across products of its different businesses. Consider automobile, motorcycle, and power equipment businesses of Honda. To the extent that customers have similar needs and preferences across cars, motorcycles, and lawn mowers (e.g., demand for high reliability, high durability, high fuel efficiency, and low emission levels), the three businesses have an opportunity to exploit similar technologies, processes, and materials in developing reliable, durable, fuel-efficient, and environmentally friendly cars, motorcycles, and lawn mowers. In addition to cross-selling the products to the same customers, they can enjoy product knowledge synergies. Firms whose businesses exchange customer and product knowledge to serve multiple needs of customers are valued higher by the stock market than firms whose businesses share factors of production, but not customer knowledge (Nayyar, 1993b).

When product knowledge relatedness or customer knowledge relatedness is missing, due to the complementarity, the value of the other can also diminish. For example, Daimler Benz's acquisition of Chrysler realized few synergies because the two firms served different markets (Harrison *et al*., 2001). Differences in customer needs, preferences, and purchasing behaviors across the two businesses overwhelmed the potential product knowledge synergies that the two businesses could have achieved by sharing similar product designs, subsystems, interfaces, and components. Doing so would produce automobiles that do not meet customer needs. Thus, related product knowledge is

a valuable source of cross-business synergy when it is complemented with related customer knowledge.

Related managerial knowledge is also a complement to related product and related customer knowledge. Existing managerial knowledge enables or constrains a firm's ability to operate in new businesses (Rumelt, 1974). In general, firms tend to enter into businesses where they can exploit their exiting managerial knowledge (Chang, 1996; Ilinitch and Zeithaml, 1995) and refrain from entering into businesses that do not match their managerial knowledge (Chang, 1996). Entering into a managerially unrelated business is difficult and costly because the learning of new managerial skills and knowledge requires unlearning of parts of organizational culture, dismantling of current power structures, and establishment of new managerial systems (Galbraith, 1983). For example, diversification of some oil companies into other extractive energy and natural resource businesses was not successful despite the relatedness of products and customer markets (Goold and Luchs, 1993). The lack of related managerial skills and knowledge might have overwhelmed the product and customer-based synergies that the oil firms had hoped to achieve in energy and natural resource businesses.

The performance impact of cross-business knowledge synergies

The distinctiveness and sustainability of a corporate strategy depends not only on doing many individual activities well but also integrating among them (Porter, 1996). Hence, achieving knowledge relatedness within product, customer, and managerial knowledge domains is necessary but not sufficient for a distinctive and sustainable strategy. There are two main reasons to expect that performance effects of the firm's knowledge synergy strategy will be contingent on the synergies arising from the complementarity of the three types of knowledge relatedness.

First, a complementary bundle of resources provides unique value to the firm (Harrison *et al.*, 2001). Each dimension of knowledge relatedness captures a different sub-additive cost synergy: i.e., reduced costs in product development activities, reduced costs in marketing and advertising activities, and reduced costs in governance of multiple business units. The overall cost-based synergies obtained from the three dimensions will be greater than the synergies obtained from any dimension alone. Further, the complementarities among the three dimensions of knowledge relatedness create super-additive value synergies. The sum of the cost-based and the value-based synergies will have a stronger effect on firm performance than the cost-based synergies alone.

Second, a system of complementarities is difficult to observe and imitate (Porter, 1996). Competitors may observe the similarities in product designs, subsystems, interfaces, and components across multiple business units of the firm. They may notice that the business units are exploiting similar marketing and advertising skills and knowledge. The managerial policies and processes by which the businesses are governed may also be obvious to the competitors. However, synergies arising from different, yet complementary resources are not as obvious to competitors as synergies arising from similar resources (Harrison *et al.*, 2001). In our case, the complementarities among the related product, customer, and managerial knowledge resources are much more difficult to observe and imitate. To start with, the competitors may lack the strategic foresight to recognize the complementarities (Milgrom and Roberts, 1995). Assuming that they recognize the complementarities, competitors have to make systemic changes in product designs, subsystems, interfaces, and components; customer interactions and marketing and advertising activities; and managerial policies and processes of their business units. They are likely to face implementation challenges and incur substantial costs and time delays. If the probability of successful imitation along one dimension is 90 percent, it will drop down to 81 percent ($0.9 * 0.9$) along two dimensions, and 73 percent ($0.9 * 0.9 * 0.9$) along three dimensions. Due to the complementarities, implementing a single dimension without implanting the others will not produce the intended performance improvements (Porter, 1996). In fact, it may even produce negative performance effects (Milgrom and Roberts, 1995). Unless they successfully match the whole system of complementarities, competitors will get little benefit from imitation (Porter, 1996).

When there are strong complementarities among a set of resources, a multibusiness firm aiming to create cross-business synergies out of them has a marked need for actively coordinating the sharing of those resources across its business units. The

simultaneous exploitation of product knowledge relatedness, customer knowledge relatedness, and managerial knowledge relatedness can be interpreted as an indication that the firm recognizes complementarities and seeks to achieve knowledge relatedness in multiple knowledge domains simultaneously. Thus, we construe the overall cross-business knowledge synergy of a multibusiness firm as a latent second-order construct. The first level of the construct captures sub-additive production cost synergies arising from knowledge relatedness within product, customer, and managerial knowledge domains, whereas the second level captures super-additive value synergies arising from the complementarity of the three types of knowledge relatedness.

In assessing performance effects of a complementary system, it is imperative to compare performance effects of individual system components with the performance effects of the full system to define the conditionality of individual effects on the effects of other system components and to ensure that the full system effects outweigh the individual component effects (Ichniowski, Shaw, and Prennushi, 1997; Whittington *et al*., 1999). To test whether performance effects of cross-business knowledge synergies are contingent on the complementarity of the three types of knowledge relatedness or whether each type of knowledge relatedness has an independent direct effect on firm performance, we specify two competing hypotheses: (1) a 'strong-form' hypothesis stating that the complementarity of the three types of knowledge relatedness will have a positive effect on corporate financial performance; and (2) a 'weak-form' hypothesis stating that each type of knowledge relatedness will have an independent direct effect on corporate performance. The weak-form hypothesis states that sub-additive production cost synergies arising from any type of knowledge relatedness can drive corporate performance but posits no significant additional explanatory power for the super-additive value synergies arising from the complementarity of the three types of knowledge relatedness.

Hypothesis 1 (strong form): Complementarity of product knowledge relatedness, customer knowledge relatedness, and managerial knowledge relatedness has a positive effect on corporate financial performance of multibusiness firms.

Hypothesis 2 (weak form): Product knowledge relatedness, customer knowledge relatedness, and managerial knowledge relatedness have independent positive direct effects on corporate financial performance of multibusiness firms.

METHODS

Our sample was the multibusiness *Fortune* 1000 firms listed in the year 2000. We used a survey to collect primary data from senior executives to measure cross-business knowledge synergies of these firms in product, customer, and managerial domains. We also obtained secondary data from the COMPUSTAT and CRSP databases to compute objective measures of firm performance and some of our control variables.

Dependent variables

We adopted three widely used objective measures of firm performance in the diversification literature as our dependent variables to test the predictive validity of the cross-business knowledge synergy constructs: return on assets (ROA), return on equity (ROE), and Tobin's Q. We computed Tobin's Q as the ratio of the market value of a firm to the replacement cost of its assets, using basic financial and accounting data from COMPUSTAT (Chung and Pruitt, 1994). We introduced a 1-year lag between knowledge synergies and firm performance, measuring knowledge synergies in 2000 and ROA, ROE, and Tobin's Q with year 2001 financial data. This lagged structure allowed us to assess whether knowledge synergies in a given year affected firm performance in the subsequent year.

Cross-business knowledge synergies

Cross-business knowledge synergy is modeled as a second-order factor model. First-order factors capture sub-additive production cost synergies arising from the relatedness of product knowledge, relatedness of customer knowledge, and relatedness of managerial knowledge. The second-order factor captures patterns of interactions and covariance among the first-order factors to capture the super-additive value synergies arising from the complementarity of the three types of knowledge relatedness.

We developed new measurement items and adapted existing measures to capture managers' perspectives on their firms' product knowledge relatedness, customer knowledge relatedness, and managerial knowledge relatedness. We also developed a new response scale that captures actual knowledge relatedness of firms as perceived by their managers. We asked our respondents whether a given knowledge resource was unique and specific to each business unit or common and applicable to multiple units (1 = unique in all or almost all of the business units, 2 = unique in a majority of the business units, 3 = unique in about half of the business units, common across the other half, 4 = common across a majority of the business units, and 5 = common across all or almost all of the business units). By emphasizing the degree to which the firm uses common knowledge resources rather than the potential applicability of knowledge resources across the businesses, we have designed our response scale to capture the actual, realized knowledge relatedness of a given business portfolio rather than potential relatedness.

We pre-tested the survey instruments with 10 domain experts in academia and 25 executives of *Fortune* 1000 firms in meetings each lasting about 45 minutes. This step allowed us to assess the face and content validity of items and ensure that executives understood the instructions, questions, and response scales of the instrument as they were intended.

Due to the challenges entailed in achieving sufficient response rates from multiple informants, we chose to use a single informant per firm in the data collection (Bagozzi and Phillips, 1982). We followed the suggestions of Huber and Power (1985) to minimize any potential measurement error that may result from the use of a single informant. To identify the most knowledgeable informants about corporate product, marketing, and managerial policies of their firms, we conducted a content analysis on publicly available lists and biographies of the officers of all *Fortune* 1000 firms. We selected corporate-level executives who had advanced to their current positions after gaining experience in the product, marketing, and strategic planning functions of their corporations. To motivate participation, we promised informants an invitation to a conference where the results of the study would be discussed with participants. To minimize the effects of elapsed time and recall problems, we asked informants general questions about the organization and management of their knowledge resources at the time of the survey. All questions were pre-tested and well structured.

Informant competency measures indicated that our informants were highly knowledgeable about the questions asked for this study (Kumar, Stern, and Anderson, 1993). We customized the surveys and cover letters sent to individual firms and informants. Four follow-up letters were mailed in the 2nd, 4th, 8th and 12th weeks after the initial survey mailing. Both the original and follow-up mailings informed recipients that a Web-based version of the survey was available for their convenience and provided them with unique passwords to the survey Web site.

Response rate

Thirty-two firms in the original sample merged with other firms, were acquired, or declared bankruptcy during data collection. The executives of 82 firms declined to participate owing to company policy. 303 multibusiness firms provided usable responses, a figure constituting a response rate of about 34 percent. Forty-eight percent of these firms operated in manufacturing industries, and 52 percent operated in service industries. There were no statistically significant differences between responding and nonresponding firms for size ($t = -1.38$, $p > 0.10$), Tobin's Q ($t = 0.42$, $p > 0.10$), ROA ($t = 0.22$, $p > 0.10$), or total diversification level ($t = 0.94$, $p > 0.10$). Early and late respondents did not differ on these measures either.

Control variables

We controlled for industry-level and firm-level factors that may influence performance of a multibusiness firm. In identifying firm-level factors, we paid attention to factors that may have a bearing on both a firm's decision to exploit cross-business knowledge synergies and the performance of the firm because omitted variables that influence both independent and dependent variables can create the endogeneity problem and invalidate conclusions in diversification research (Campa and Kedia, 2002).

Relatedness of firm's businesses

Relatedness of firm's businesses can provide opportunities to exploit cross-business knowledge

synergies and influence corporate performance (Palepu, 1985; Farjoun, 1994; Robins and Wiersema, 1995). We control for three established measures of business relatedness: (1) DR, the related component of the entropy measure of diversification (Palepu, 1985); (2) human resource relatedness (Farjoun, 1994); and (3) technological relatedness (Robins and Wiersema, 1995). We computed DR using Palepu's (1985) formulas. We measured human resource relatedness by asking informants whether the professional skills and knowledge used in developing the products and/or services of their corporations were unique and specific to each business unit or common and applicable across multiple business units. We measured technological relatedness similarly, asking the informants whether the patents used in their corporations were unique and specific to each business unit or common and applicable across multiple business units. We also used these relatedness measures to assess the nomological validity of the new knowledge relatedness constructs developed in this study.

Firm size

Large size may increase performance of multibusiness firms by offering a higher potential for exploiting knowledge-based synergies or it may decrease firm performance by leading to costs arising from managerial diseconomies (Nayyar, 1993a). To control for firm size, we computed the logarithm of the total number of a firm's employees.

Risk level

In considering opportunities for cross-business knowledge synergy exploitation, managers will prefer the least risky initiative among a set of initiatives that have equal expected returns. The omission of the risk level of the firm's business portfolio can result in misleading interpretations of the performance of diversified firms (Bettis and Mahajan, 1985). Hence, we controlled for risk level. In models that used a market-based measure of firm performance (Tobin's Q models), we controlled for firm betas that are derived from the Capital Asset Pricing Model (CAPM). In models that used accounting-based measures of firm performance (ROA or ROE models), we controlled for the corresponding downside risk measure (Miller and Leiblein, 1996). The downside risk of a firm in a given year was computed as its shortfalls in accounting performance relative to average industry performance over the previous 5 years.[2]

Past performance of the firm

Poorly performing firms tend to diversify (Campa and Kedia, 2002). Not taking into account past performance may result in attributing performance effects to failure of the firm in exploiting cross-business knowledge synergies rather than to poor prior performance. Hence, we control for firm performance in the previous year.

Industry performance

To account for industry effects on firm performance, we respectively controlled for average industry Tobin's Q, average industry ROA, and average industry ROE in models using Tobin's Q, ROA, and ROE as measures of firm performance.

Assessment of measurement and structural properties

We used a confirmatory factor analytic approach within LISREL 8.3 (Joreskog and Sorbom, 1996). To minimize the potential problem of interpretational confounding, we established the validity of the measurement model prior to testing the structural model (Byrne, 1998). Doing so minimizes misfit in the measurement model so that any misfit in the overall structural model can be attributed to structural relationships.

Although we conceptualized cross-business knowledge synergies as a second-order construct, we also recognized plausible alternative specifications for the relationships between a high-level construct and its dimensions (Law, Wong, and Mobley, 1998). We specified various alternative measurement models at the first-order and second-order levels and assessed their relative fits. We validated the measurement properties in multiple stages. First, we used an item purification process to identify a set of items that parsimoniously captured the variance in the data and eliminated unreliable items. Second, we assessed the measurement properties of the individual first-order

[2] Results were robust when risk was computed with standard deviation of ROA (or ROE) over a 5-year period.

factors. Third, we assessed the relative fits of alternative first-order measurement models. Finally, we assessed the presence of a second-order factor accounting for the patterns of interactions and covariance among the first-order factors.

RESULTS

Measurement model

Internal consistency of measurements

Table 1 provides the response scale, final measurement items, and reliability measures of the first-order factors. We confirmed cross-business knowledge synergy to be a second-order construct that captures complementarities among related knowledge resources within product, customer, and managerial knowledge domains: (1) relatedness of internal product knowledge, (2) relatedness of external product knowledge acquired from R&D and manufacturing alliances of individual businesses, (3) relatedness of customer knowledge, (4) relatedness of risk and investment management processes, and (5) relatedness of alliance management processes. As the last columns of Table 1 indicate, the coefficient alpha values of all the first-order factors are above the suggested threshold value of 0.70, providing evidence of the measures' reliability (Nunnally, 1978). The composite measure reliability (ρ_c) scores are also above the suggested threshold of 0.50, demonstrating the internal consistency of the measures.

Dimensionality and convergent and discriminant validity

Second, we tested the dimensionality and convergent and discriminant validity of the knowledge synergy construct by comparing four alternative measurement models. Model 1 has a unidimensional first-order factor that accounts for the variance among all 13 items. In Model 2, the 13 items

Table 1. Response scale, final measurement items, and reliabilities for knowledge relatedness

	Response scale		
1.	Unique in all or almost all of the business units		
2.	Unique in a majority of the business units		
3.	Unique in about half of the business units, Common across the other half		
4.	Common across a majority of the business units		
5.	Common across all or almost all of business units		
	Measurement items	**Alpha**	**ρ_c**
	In <<Insert Company Name>>: (customized to each company)		
	Product knowledge relatedness	0.85	0.83
1.	Subsystems, which are self-contained groups of functionality in products/services, are ...		
2.	Interface designs, which define how subsystems of products/services interact with each other, are ...		
3.	Components, which are functionally distinct parts that make up subsystems, are ...		
4.	R&D skills and knowledge that we acquire from R&D or operations alliances are ...		
5.	Professional skills and knowledge (e.g., in engineering, law, finance and consulting domains) that we acquire from R&D or operations alliances are ...		
	Customer knowledge relatedness	0.79	0.60
1.	Characteristics of customers of our corporation are ...		
2.	Needs, preferences and purchase behaviors of our customers are ...		
3.	Business and industry conditions of our institutional customers are ...		
4.	Customer knowledge (e.g., customer needs, preferences, and behaviors) that we acquire through marketing and distribution alliances of our business units is ...		
	Managerial knowledge relatedness	0.77	0.73
1.	Processes developed for investment management are ...		
2.	Processes developed for risk management are ...		
3.	Processes developed for entering into strategic alliances are ...		
4.	Processes developed for management of strategic alliances are ...		

form five uncorrelated, independent first-order factors. Model 3 has the 13 items forming five correlated first-order factors. Finally, in Model 4 we posit a second-order factor that accounts for the relationships among the five first-order factors.

Comparison of Model 1 ($\chi^2 = 1366.93$, d.f. = 65) and Model 2 ($\chi^2 = 633.14$, d.f. = 65) shows that Model 2 is a better-fitting model (has a lower chi-square for the same degrees of freedom), indicating that a multidimensional model comprising of five uncorrelated first-order factors is superior to a unidimensional first-order factor model. Hence, we obtained support for the *multidimensionality* of the first-order knowledge relatedness constructs.

Further comparison of two nested models, Model 2 and Model 3, indicated that the unconstrained Model 3 ($\chi^2 = 257.78$, d.f. = 55), with its five freely correlated first-order factors, is superior to the constrained Model 2, with its five uncorrelated first-order factors ($\Delta\chi^2 = 375.36$, Δd.f. = 10, $p < 0.0001$). In Model 3, the standardized 'loadings' of the measurement items on their respective factors are all highly significant ($p < 0.001$), providing support for *convergent validity*.

The superiority of Model 3 (unconstrained) over Model 2 (constrained) indicates that pairs of correlations among the first-order factors are significantly different from zero. They are also below the cut-off value of 0.90 (Bagozzi, Yi, and Phillips, 1991), demonstrating the distinctiveness of the theoretical content captured by the individual first-order factors. The measurement items' convergence on their respective factors and the factors' distinctness from each other support our construct's *discriminant validity* (Bagozzi and Phillips, 1982).

First-order vs. second-order factor models

Finally, we tested whether a second-order factor explained complementarities among the five first-order factors by accounting for their patterns of interactions and covariance. To test for the presence of second-order factor models, Marsh and Hocevar (1985) developed the target coefficient (T) statistic, which is the ratio of the chi-square value of the first-order factor model to the chi-square value of the second-order factor model. The target coefficient has an upper limit of 1.0. Therefore, support for the existence of a second-order factor becomes stronger as T approaches unity (Marsh and Hocevar, 1985). A complementary set of statistics is given by the significance of the parameters reflecting the second-order factor loadings (Venkatraman, 1990). For the second-order knowledge synergy construct, the target coefficient value is 0.83, indicating that a second-order factor accounts for 83 percent of the relations among the first-order factors. More importantly, all second-order factor loadings ($\gamma[1, 1]) - \gamma[5, 1])$ are highly significant ($p < 0.001$), providing further justification for the acceptance of the second-order factor model.

Collectively, these results support the multidimensionality, convergent and discriminant validity, and reliability of a second-order knowledge synergy construct.

Descriptive statistics and correlations

Descriptive statistics and correlations among the constructs of the study are summarized in Table 2. Knowledge synergies have positive and significant associations with Tobin's Q, ROA, and ROE.

An examination of the nomological relationships among knowledge synergy, human resource relatedness (HRR), and technological relatedness (TR) reveals that knowledge synergy has highly significant associations with HRR ($r = 0.63$, $p < 0.0001$) and TR ($r = 0.67$, $p < 0.0001$). However, comparison of alternative measurement models respectively modeling HRR and TR (1) as part of the knowledge synergy construct ($\chi^2 = 476.24$, d.f. = 85) and (2) as independent constructs ($\chi^2 = 743.53$, d.f. = 87) reveal that knowledge synergy, HRR, and TR are independent constructs ($\Delta\chi^2 = 267.29$, Δd.f. = 2, $p < 0.0001$). Collectively, these findings provide evidence for nomological validity of the knowledge synergy construct.

As for the related component of the entropy measure of diversification (DR) (Palepu, 1985), the correlation between knowledge synergy and DR is significant but negative ($r = -0.21$, $p < 0.001$). It is interesting to note that DR also has significant and negative correlations with HRR ($r = -0.16$, $p < 0.01$) and TR ($r = -0.20$, $p < 0.001$). These findings are consistent with the arguments that indirect measurements of relatedness with industry-level data, such as DR, diverge from direct measurement of relatedness with firm-level

Table 2. Summary statistics and correlation matrix

	Year	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Tobin's *Q*	2001	1.33	0.81	1.00																
2. ROA	2001	0.03	0.05	0.57***	1.00															
3. ROE	2001	0.07	0.16	0.50***	0.88***	1.00														
4. Past performance (Tobin's *Q*)	2000	1.41	0.99	0.92***	0.48***	0.43***	1.00													
5. Past performance (ROA)	2000	0.23	0.09	0.60***	0.41***	0.37***	0.60***	1.00												
6. Past performance (ROE)	2000	0.39	0.14	0.40***	0.36***	0.44***	0.40***	0.80***	1.00											
7. Knowledge synergy	2000	3.01	0.77	0.22***	0.18**	0.19***	0.25***	0.16**	0.21***	1.00										
8. Human resource relatedness (HRR)	2000	3.29	1.14	0.09	0.08	0.11†	0.11†	0.06	0.08	0.63***	1.00									
9. Technological relatedness (TR)	2000	2.94	1.51	0.09	0.02	0.04	0.13*	0.05	0.06	0.67***	0.52***	1.00								
10. Related diversification (DR)	2000	0.40	0.39	−0.01	0.10	0.14*	−0.06	−0.02	0.05	−0.21***	−0.16**	−0.20***	1.00							
11. Firm size	2000	4.20	0.50	0.14*	0.18**	0.16**	0.13*	0.04	0.08	0.11†	0.10	−0.02	0.00	1.00						
12. Industry performance (Tobin's *Q*)	2001	1.21	0.32	0.28***	0.08	0.07	0.30***	0.31***	0.26***	0.09	0.12*	0.09	0.12*	0.06	1.00					
13. Industry performance (ROA)	2001	−0.07	0.07	−0.07	0.11†	0.11†	−0.14*	−0.12*	−0.03	0.05	0.01	0.03	−0.21***	−0.03	−0.57***	1.00				
14. Industry performance (ROE)	2001	−0.01	0.07	0.00	0.20***	0.22***	−0.06	−0.05	0.05	0.05	0.02	0.04	−0.16**	−0.01	−0.25***	0.83***	1.00			
15. Downside risk (ROA)	2000	0.01	0.02	−0.21***	−0.20***	−0.13*	−0.19***	−0.18**	−0.02	−0.06	0.02	−0.05	−0.08	0.01	−0.01	−0.11†	−0.11†	1.00		
16. Downside risk (ROE)	2000	0.03	0.04	−0.24***	−0.22***	−0.17**	−0.23***	−0.27***	−0.16**	0.04	0.02	0.10	−0.09	−0.01	0.03	−0.04	−0.01	0.66***	1.00	
17. Beta	2000	0.64	0.48	0.21***	−0.19***	−0.21***	0.35***	0.22***	−0.04	0.08	0.12*	−0.01	−0.14*	0.02	0.16**	−0.35***	−0.41***	0.08	−0.03	1.00

Note: $n = 303$ † $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

data (Nayyar, 1992) such as the knowledge relatedness, human resource relatedness, and technological relatedness measures of this study.

Test of hypotheses

Due to the intractability of higher-order interactions, researchers theorizing about the complementarity of three or more variables resort to the use of pair-wise interaction tests to test their complementarity hypotheses. They include main variables and their pair-wise interactions in a regression equation and test for the significance of the pair-wise interaction terms as evidence of complementarity. It was not appropriate to use the pair-wise interaction test approach in this study for three reasons.

First, there are highly significant correlations between product knowledge relatedness and customer knowledge relatedness ($r = 0.38$, $p < 0.001$); product knowledge relatedness and managerial knowledge relatedness ($r = 0.39$, $p < 0.001$); and customer knowledge relatedness and managerial knowledge relatedness ($r = 0.25$, $p < 0.001$). Further, the multiplicative pair-wise interactions of these variables are also highly correlated with each other and with the variables from which they are computed (correlations range from $r = 0.41$ to $r = 0.85$, all significant at $p < 0.001$ level). When the main variables and their pair-wise interactions are so highly correlated with each other, coefficient estimates obtained from the regression equation do not reflect inherent effects of any particular independent variable on the dependent variable but only marginal or partial effects, given the other, correlated independent variables in the model. While the high level of intercorrelations is a problem for using the pair-wise interaction test, it is consistent with the theory of complementarities, which predicts high levels of interaction and covariance among the components of a system of complements (Milgrom and Roberts, 1990, 1995).

Second, the pair-wise interaction test assumes that the complementarities exist at the level of pairs of variables. Our theory is about the performance effects of multilateral interactions among product knowledge relatedness, customer knowledge relatedness, and managerial knowledge relatedness. But the pair-wise interaction test is not capable of detecting multilateral interactions and covariance implied by the theory of complementarities (Whittington *et al*., 1999).

Third, the pair-wise interaction test is also used to test for other theoretical relationships such as the 'fit' between two variables or the 'moderation' effect of one variable in the performance relationship of the other variable (Drazin and Van de Ven, 1985; Arnold, 1982; Venkatraman, 1989). Thus, it is not clear whether the significance of the pair-wise interaction term provides empirical evidence for the 'complementarity' of the variables, the 'fit' of the variables, or the 'moderation' effect of one variable in the performance relationship of the other variable. Such interpretational confounding can break down the sophisticated theoretical development and explanation behind our complementarity hypothesis.

Thus, we sought for an alternative statistical method that could account for the multilateral interactions and covariance among our main variables. A second-order factor modeling approach provides a plausible alternative (Rindskopf and Rose, 1988). To test our strong-form (complementarity) and weak-form (direct effects) hypotheses, we respectively used the structural models depicted in Figures 1 and 2. The complementarity model in Figure 1 includes a second-order factor model of the knowledge synergy construct. A second-order factor is a general entity that is manifested or reflected by some first-order factors serving as its indicators (Williams, Gavin, and Hartman, 2004). The second-order factor is the main source of covariance among the first-order factors. It explains why the first-order factors coexist and co-vary with each other (Rindskopf and Rose, 1988). In Figure 1, different types of knowledge relatedness are modeled as first-order factors (indicators) of the knowledge synergy construct. When taken independently, these first-order factors capture sub-additive production cost synergies arising from the relatedness of knowledge resources within product, customer, and managerial knowledge domains. The second-order factor models the complementarity of the first-order factors by accounting for their multilateral interactions and covariance (Rindskopf and Rose, 1988). The directions of the structural links are from the second-order factor to the first-order factors, indicating that a multibusiness firm that is in pursuit of knowledge synergy seeks to achieve knowledge relatedness in a complementary set of knowledge domains simultaneously.

Figure 2 shows the direct effects model used for testing Hypothesis 2. This model includes only

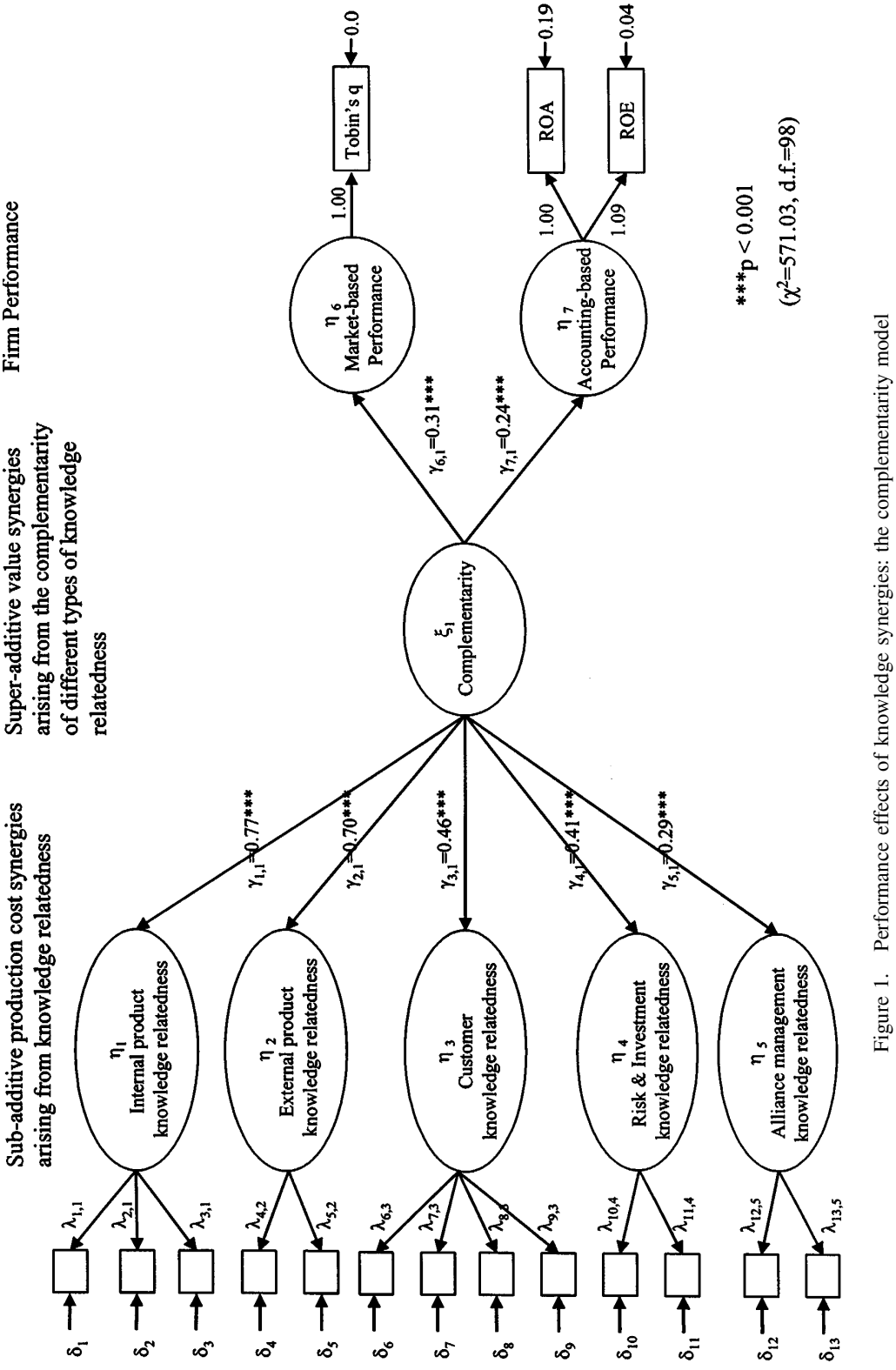

Figure 1. Performance effects of knowledge synergies: the complementarity model

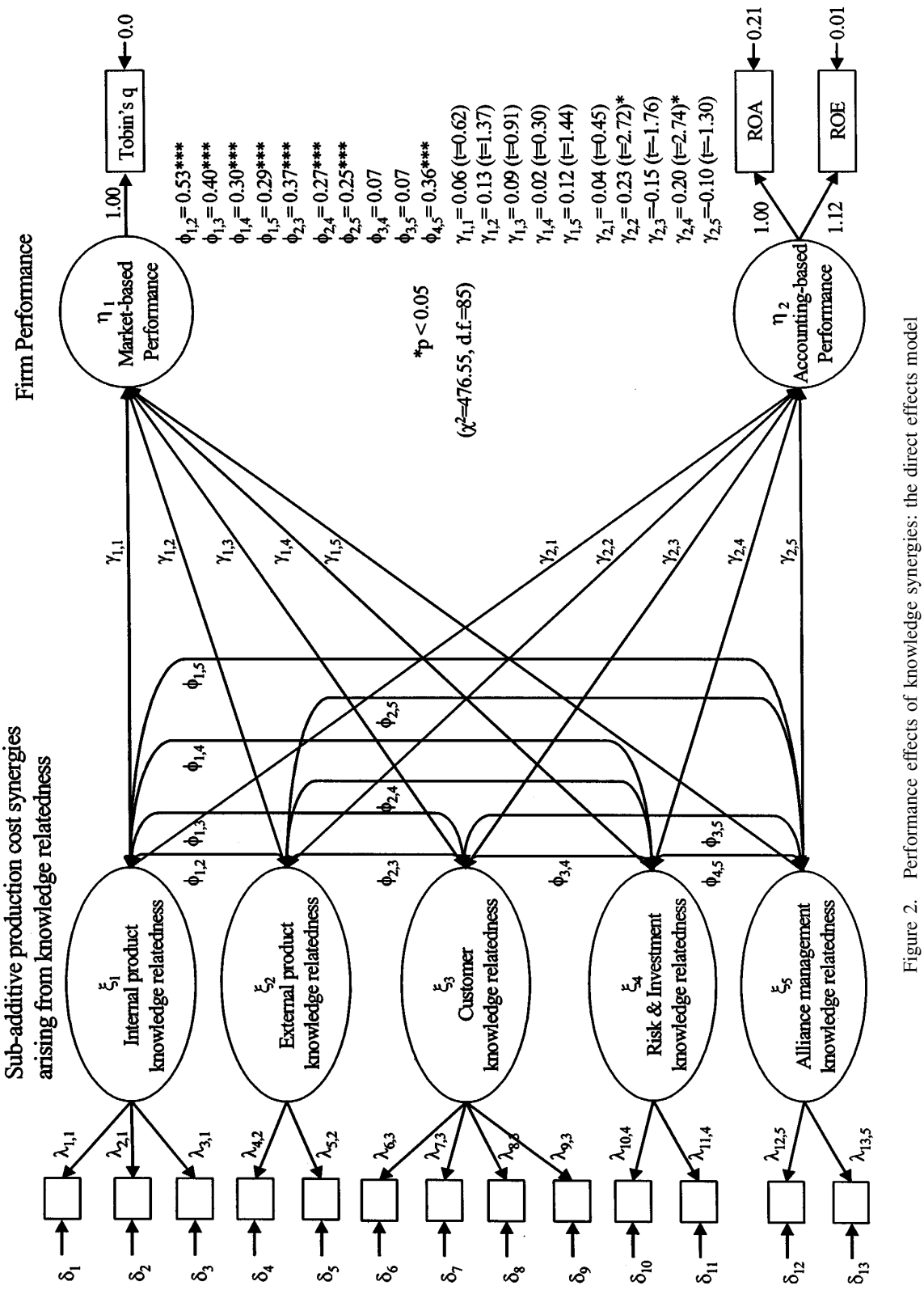

Figure 2. Performance effects of knowledge synergies: the direct effects model

the first-order factors and models their pair-wise covariance. It states that any type of knowledge relatedness can have a direct effect on firm performance. But unlike the complementarity model in Figure 1, the direct effects model does not include a second-order factor accounting for the covariance of the first-order factors. Put differently, the direct effects model does not posit any incremental explanatory power for the complementarity of the different types of knowledge relatedness.

In Figure 1, the structural link from complementarity to market-based performance (Tobin's Q) is positive and significant (structural link $= 0.31$, $p < 0.001$). The structural link from complementarity to accounting-based performance (ROA and ROE) is also positive and significant (structural link $= 0.24$, $p < 0.001$). These findings provide support for Hypothesis 1, the strong form of the two competing hypotheses. They indicate that a second-order factor accounting for the complementarity of different types of knowledge relatedness has a positive effect on firm performance. In Figure 2, the direct effects model, only two of the 10 structural links from the knowledge relatedness constructs to performance constructs are significant. Thus, Hypothesis 2, the weak form of the two competing hypotheses, is not supported.

Test of alternative explanations

After finding support for the complementarity model in Figure 1, we added the control variables into the model to assess if the related diversification component (DR) of the entropy measure of diversification (Palepu, 1985), human resource relatedness (Farjoun, 1994), technological relatedness (Robins and Wiersema, 1995), firm size, risk level of the firm's business portfolio, past performance of the firm, and industry performance could provide alternative explanations for our findings. Second, third, and fourth columns of Table 3 present the results respectively for Tobin's Q, ROA, and ROE models. In the presence of all controls, knowledge synergy still had significant associations with Tobin's Q (structural link $= 0.21$, $p < 0.001$), ROA (structural link $= 0.21$, $p < 0.001$), and ROE (structural link $= 0.17$, $p < 0.001$). Knowledge synergy accounts for about 4 percent of the variance in each of the three performance measures after controlling for the variance explained by the control variables. Based on these findings, the most plausible alternative explanations to the performance effects of knowledge synergy can be ruled out.

Table 3. Performance effects of knowledge synergy in the presence of control variables

Independent variables	Dependent variable (D.V.)		
	Tobin's Q	ROA	ROE
Knowledge synergy	0.21***	0.21***	0.17***
Control variables			
Related diversification (DR)	−0.01	0.16**	0.17***
Human resource relatedness (HRR)	−0.06	−0.02	0.00
Technological relatedness (TR)	−0.10*	−0.12*	−0.07
Firm size	−0.03	0.14**	0.11*
Firm risk measures			
Beta (from CAPM)	−0.30***		
Downside risk (using ROA as performance)		−0.10*	
Downside risk (using ROE as performance)			−0.10*
Past performance of the firm			
Tobin's Q $(t-1)$	0.92***		
ROA $(t-1)$		0.38***	
ROE $(t-1)$			0.36***
Industry performance measures			
Industry Tobin's Q	−0.01		
Industry ROA		0.17***	
Industry ROE			0.23***
Squared multiple correlations for structural equations (analogous to model R^2)	0.75	0.28	0.27

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

DISCUSSION AND CONCLUSIONS

This study synthesized the resource-based view of diversification and the economic theory complementarities to conceptualize cross-business knowledge synergies of a multibusiness firm in terms of the relatedness and the complementarity of knowledge resources used across business units. It also assessed performance effects of knowledge synergies using multiple objective measures of market-based and accounting-based firm performance.

Theoretically, this study overcomes two major weaknesses observed in prior research on cross-business synergies in multibusiness firms. Most diversification studies focus on individual manifestations of a firm's cross-business synergies by examining sources of synergy in selected functional domains. For example, they examine product relatedness, manufacturing relatedness, R&D relatedness, or technological relatedness to capture cross-business synergies in the product domain; market relatedness and advertising relatedness to capture synergies in the customer domain; or managerial relatedness to capture synergies in the managerial domain. This study conceptualized cross-business knowledge synergy as a cohesive, multidimensional corporate strategy, which drives knowledge relatedness in a complementary set of knowledge domains simultaneously. The superiority of the complementarity model in Figure 1 to the direct effects model in Figure 2 confirms that the multiple manifestations of knowledge relatedness in product, customer, and managerial knowledge domains are all driven by a cohesive knowledge synergy strategy.

Second, unlike most prior studies, which focused only on the similarity (relatedness) of resources as a source of cross-business synergy, this study recognized that the complementarity of different resources can also serve as an important source of synergy (Milgrom and Roberts, 1995), and an important basis for differentiating a firm's corporate strategy (Porter, 1996). The complementarities view of resource-related diversification developed in this study extends the resource-based view of related diversification (Robins and Wiersema, 1995). While the resource-based view recognizes that the exploitation of common product, customer, or managerial knowledge resources across multiple businesses can respectively create product knowledge synergies, customer knowledge synergies, and managerial knowledge synergies, it does not recognize the synergies arising from the complementarity of different types of knowledge relatedness. With its second-order, multidimensional conceptualization of cross-business knowledge synergy, this study captures both the sub-additive production cost synergies arising from the relatedness of knowledge within product, customer, and managerial knowledge domains, and the super-additive value synergies arising from the complementarity of different types of knowledge relatedness.

As the rich literature stream on the relationship between related diversification and firm performance indicates, conceptualizing individual dimensions of a multidimensional relatedness strategy as independent strategies and examining their performance effects separately may lead to inconsistent and confusing results. If we had treated each type of knowledge relatedness as independent, as shown in Figure 2, we would have incorrectly concluded that relatedness in product knowledge, customer knowledge, or managerial knowledge domains did not have any significant effects on firm performance. By modeling the complementarity of different types of knowledge relatedness, we were able to discover that the performance effects of knowledge relatedness are achieved not through the isolated sub-additive production cost synergies in product, customer, or managerial knowledge domains per se, but through the super-additive value synergies that result from their coexistence and complementarity.

Another theoretical advance of this study is that, in addition to examining relatedness of a firm's internally generated knowledge resources, it also examines the relatedness of external knowledge resources that business units of the firm acquire from their alliance partners. Two of the new measures capture relatedness of product knowledge acquired through R&D and manufacturing alliances of the business units. A third measure captures the relatedness of customer knowledge acquired through marketing and distribution alliances. As firms increasingly turn to strategic alliances for developing, manufacturing, and selling their products and services, knowledge acquired from alliance partners becomes an important source of synergy. By learning from the alliance partners of individual businesses and exploiting that learning in other business units as well, diversified firms can create cross-business knowledge synergies. As two of the four managerial knowledge relatedness measures

indicate, to exploit such synergies diversified firms may need to manage individual alliances of their businesses as part of a corporate-level portfolio of alliances.

Methodologically, this study makes three major contributions. First, it measures knowledge relatedness directly at the firm level by collecting data from managers of the firm instead of inferring it from industry participation of the firm and the resource similarities of industries. Since the managers' view of relatedness departs significantly from what is captured by external observations and approximations of relatedness (Nayyar, 1992; Prahalad and Bettis, 1986; Stimpert and Duhaime, 1997), the direct measurement of knowledge relatedness at the firm level is a major methodological contribution that heeds the calls for increasing the correspondence between resource-based views of relatedness and operational measures of relatedness (Farjoun, 1994; Markides and Williamson, 1994; Robins and Wiersema, 1995). Second, this study develops a new response scale that captures actual relatedness rather than potential relatedness (Nayyar, 1992). Since the relatedness hypothesis of the diversification research is about performance effects of actual resource sharing among business units of a diversified firm, it is important to capture the extent of actual resource sharing rather than the potential for resource sharing. The new response scale will allow future studies to conduct better tests of the relatedness hypothesis by enabling the measurement of actual rather than potential resource relatedness of business portfolios. Third, the new measurement items are designed and validated to capture knowledge relatedness of both service and manufacturing businesses. Prior relatedness measures were developed, validated, and applied almost exclusively in the manufacturing sectors (Gassenheimer and Keep, 1998; Nayyar, 1992). Given that service sectors constitute a significant portion of the economy, and that business portfolios of many diversified firms contain both service and manufacturing businesses, the development of measures that are applicable in both contexts is a major methodological contribution that can allow more diversification studies in the service sectors and more accurate measurement of the relatedness of business portfolios containing both service and manufacturing businesses.

With these theoretical and methodological improvements, this study was able to detect performance effects of cross-business knowledge synergies using both backward-looking accounting-based performance measures (ROA and ROE) and forward-looking market-based performance measures (Tobin's Q). We ruled out potential alternative explanations to these findings by testing alternative measurement models for the knowledge synergy construct, by benchmarking it with three established measures of relatedness (DR, HRR, and TR), and by controlling for size, risk level, past performance, and industry performance of firms.

Our findings also have important implications for practice. They indicate that the knowledge relatedness of a business portfolio is defined by a complementary set of knowledge resources. Firms seeking to expand into related businesses should explore not only whether their individual product, customer, or managerial knowledge resources are applicable in the new business but also whether successful operation in the new business requires the complementarity of those knowledge resources. If one of the complementary knowledge resources required by the new business is missing, the diversification move may not succeed despite the presence of other types of related knowledge resources. Our findings suggest that diversification moves are most likely to succeed when the firm exploits a complementary set of product, customer, and managerial knowledge resources in the new business. Sporadic and isolated attention to the relatedness of an individual knowledge resource may not suffice for successful diversification and superior corporate performance.

Before we conclude, we would like to point out some limitations of this study and offer them as possible avenues for extensions. First, the dimensionality of cross-business knowledge synergies is limited to three types of knowledge resources. Out of a concern for developing a construct that parsimoniously captures the most strategic knowledge-based synergies of the firm, we left out other intangible sources of synergy such as brands and reputation. Future work can assess whether the exploitation of a common corporate brand and common reputation across multiple businesses creates synergies that explain variance in corporate performance over and beyond the variance explained by the three dimensions of knowledge relatedness examined in this study. Second, given our concern to detect performance effects of knowledge relatedness in a large, cross-sectional sample, we

adopted an outcomes approach rather than a mechanisms approach to the measurement of knowledge relatedness. We did not theorize about or measure the antecedent mechanisms that give rise to knowledge relatedness in product, customer, and managerial knowledge domains. We did not examine how firms coordinate among the three knowledge domains to achieve complementarities either. What organizational structures and processes can be designed to enhance knowledge relatedness? What is the role of information systems in leveraging a complementary set of related knowledge resources across business units? Further work on such antecedent mechanisms may allow us to better understand how organizations should be designed to capture value from knowledge-based synergies. Third, our cross-sectional data do not allow us to entirely rule out the possibility that unobserved factors may be driving our results. Future studies can more effectively address potential endogeneity problems by using panel data and a fixed effects model. Finally, the computation of the new knowledge relatedness measures entails some costs and challenges. Unlike other relatedness measures, which can be computed with readily available data in public archival sources, the new measures require primary data collection from executives of firms.

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