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THE INDEPENDENT AND JOINT EFFECTS OF THE SKILL AND PHYSICAL BASES OF RELATEDNESS IN DIVERSIFICATION

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By examining the independent and joint effects of the skill and physical bases of relatedness, this study develops a multidimensional view of relatedness in diversification. The paper compares the ways the two bases identify relatedness, and examines empirically the relationship between relatedness and performance for a sample of 158 large diversified manufacturing firms. Each base of relatedness alone had no significant effect on financial performance. However, when the two approaches were combined, there was a strong positive effect on most indicators of performance. The findings demonstrate how different bases of relatedness complement and extend one another, and they clarify findings of previous studies that used a single base of relatedness. © 1998 John Wiley & Sons, Ltd.

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INTRODUCTION

Relatedness, the logic and extent by which a firm's different lines of business (or industries) are connected, has important research and practical implications (Rumelt, 1974; Wrigley, 1970). In particular, new approaches to the assessment and measurement of relatedness have provided important insights regarding firm diversification strategy and performance (Amit and Livnat, 1988; Ginsberg, 1990; Grant, Jammine and Thomas, 1988; Montgomery, 1982; Palepu, 1985; Pitts and Hopkins, 1982; Prahalad and Bettis, 1986; Nayyar, 1992a; Rumelt, 1974; Seth, 1990; Wrigley, 1970). Firms and industries can be viewed as collections of interrelated activities (Porter, 1985) and resources (Penrose, 1959), so relatedness between a firm's different lines of business (or industries) can manifest itself along many different dimensions (Grant *et al*., 1988; Mintzberg, 1988). Yet, despite the multiplicity of approaches to relatedness, the idea that relatedness encompasses several dimensions has not been adequately researched. The view of relatedness as multidimensional calls for an appreciation both of the implications of *choosing* one among several criteria for relatedness, and of *combining* different bases of relatedness.

Choosing a particular dimension or base of relatedness has important implications. A diversification pattern attributed by a researcher to one motive (e.g., increased earnings through cross-selling of products) may in fact be the result of another (e.g., cost reduction due to economies of scope in purchasing). Furthermore, the ways a given sample of firms can potentially be divided into subsets of related and unrelated diversified firms depend directly on the way relatedness is identified and measured. The conflicting results regarding performance differences between related and unrelated diversification strategies may, in fact, be a result of the different ways of categorizing diversification strategies (Grant *et*

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al., 1988; Hoskisson and Hitt, 1990; Ramanujam and Varadarajan, 1989). Another important, and often overlooked benefit of using multiple views of relatedness is that it can help existing firms identify different sources of potential competition and opportunities for diversification (Chatterjee and Wernerfelt, 1991; Montgomery and Hariharan, 1991). Clearly, the *choice* of a particular approach to assess relatedness is not just a matter of methodological convenience: it can significantly affect the evaluation of the motives and the consequences of diversification.

No less important are the implications of *combining* different dimensions of relatedness. These implications are usually not addressed in diversification research. Theoretical arguments for diversification such as economies of scope (e.g., Panzar and Willig, 1981; Teece, 1982) usually center around the benefits of using a *particular* resource (e.g., know-how) in several lines of business, and rarely discuss the implications of the firm's expansion using several related resources (see Chatterjee, 1990, for an exception). Similarly, empirical research has usually looked at how an individual resource or base of relatedness evokes a diversification pattern without regard to the interaction among several resources (Lemelin, 1982; Chatterjee and Wernerfelt, 1991). Given the existence of multiple ways to assess relatedness, the overall degree of relatedness (and consequently its combined or net expected performance benefits) must be determined. Thus, a combined assessment of bases of relatedness has both theoretical and practical significance.

This study focuses on two important bases of relatedness: skills and physical characteristics. Although other bases of relatedness are undoubtedly important, such as having the same customer group or leveraging the same reputation, the physical and the skill bases of relatedness have been singled out in the literature as fundamental (Chandler, 1962; Chatterjee and Wernerfelt, 1991; Penrose, 1959; Rumelt, 1974; Teece, 1982). The physical base concerns relations between the physical characteristics of products, whereas the skill base may consist of research and development teams, experienced salesmen, and managerial and other skills common to two or more products (Gort, 1962: 57–58).

Similarity or complementarity of the *physical* attributes of products is the overarching criterion for relatedness used by the Standard Industrial Classification (SIC) Code (Gort, 1962: 57–58). Several criteria such as raw materials, production processes, and end uses are used to categorize establishments into industries and then into industry groups (*Standard Industrial Classification Manual*, 1987). Encouraged by Montgomery's (1982) study, studies using SIC-based measures have looked at such central issues as the role of resources in diversification (e.g., Chatterjee and Wernerfelt, 1991), and the relationship between diversification and performance (e.g., Amit and Livnat, 1988; Palepu, 1985).

A motivation for the current study is to present a recently developed approach that captures the skill base of relatedness (Farjoun, 1994). This new approach coincides with the growing interest in intangible resources—in particular, human skills—shared by researchers interested in the emerging resource-based view (e.g., Barney, 1991; Mahoney and Pandian, 1992; Penrose, 1959; Teece, 1982; Wernerfelt, 1984), and by practitioners who view these resources as essential to firm success (Hall, 1992). A key advantage of the skill base classification we use over other measures of skills, such as R&D and advertising intensities, is its direct comparability to the physical base used in existing SIC measures of relatedness. Like physical base SIC measures of relatedness and diversification, the new approach uses the SIC code to identify individual lines of business within a firm. The similarity among those lines of business is used as an indirect indicator of diversification related to firm-specific resources (e.g., know-how).

Unlike traditional SIC measures though, the new concept of relatedness views each industry or line of business as a combination of occupational skills or bodies of knowledge required to produce a product. Consequently, the relatedness of different industries is determined by similarity in skill combinations (e.g., aeronautic engineers and physical scientists), rather than by similarity in the physical attributes of products in the same industry group (i.e., 2-digit SIC code). The skill base approach also differentiates lines of business across a broader range of skills (e.g., engineering and production skills), and at a higher level of detail (e.g., precision vs. assembly types of production) than other measures of skills.

The main objective of this paper is to further develop the notion of relatedness as multidimensional. No previous study has used a skill-based measure of relatedness to examine the performance implications of diversification, or attempted to compare its merits with those of more traditional bases. It is useful to *juxtapose* the physical and skill bases of relatedness, in order to promote a better understanding of the underlying assumptions, relative merits and limits of these bases, and add to the insights already gained from using different concepts and measures of relatedness and diversification (e.g., Nayyar, 1992a; Prahalad and Bettis, 1986; Rumelt, 1974). The purpose of *synthesizing* different bases of relatedness is to address a relatively underdeveloped aspect of diversification research—the theoretical, empirical, and practical implications of combining complementary bases. The foregoing discussion leads us to examine two specific questions:

Q1: How do the skill and physical bases differ in the ways they identify relatedness in the same set of industries (or lines of business)?

Q2: What are the separate *and* joint *contributions of the two approaches in explaining firm performance differences?*

The physical and skill bases of relatedness are conceptually distinct. Yet, in practice a firm's lines of business may be related on both bases. They differ when physical resources are natural materials and processes, and when human skills, like those associated with information or with other people, are not directly applied to physical objects. The two bases come together when material aspects of products and production are artifacts of human skills. These basic relationships between physical and skill resources form the foundation of the theoretical arguments developed in the next section.

THE INDEPENDENT EFFECTS OF THE PHYSICAL AND SKILL BASES OF RELATEDNESS

Underlying the physical base of relatedness is a concept of firms or industries as collections of material resources and physical processes. Elements of these collections are raw materials, physical processes, plant and equipment, manuals and blueprints, and computer hardware and software, among others. By contrast, the human skill base concept views firms or industries as sets of interrelated bodies of human knowledge that come together in the process of providing goods and services.

The differences between physical and skill resources and activities have explicit implications for firm diversification. Human skills are not easy to identify.[1] Individuals cannot always articulate what they know (Polanyi, 1967), and there is uncertainty about the new domains to which their knowledge can be successfully applied. Additionally, individuals are distinguished from physical resources by their ability to learn and improve their services, to transfer their knowledge from one domain to many others, and to combine resources in increasingly productive ways (Penrose, 1959). By contrast, physical resources are much more observable and identifiable than skills (Itami and Roehl, 1987). This may result in focusing the *search* for diversification outlets initially on applications for physical artifacts, thus constraining the range of diversification opportunities considered.[2] Additionally, because physical resources are usually more product-specific than other resources, the range of industries to which they *can be applied* is more limited (Chandler, 1962; Chatterjee and Wernerfelt, 1991).

The differences between the two bases also affect the way relatedness between two (or more) industries (or line of business) is identified. First, when relatedness is primarily in production, each base may point to a different aspect of production relatedness (e.g., similarity in facilities vs. similarity in production expertise). Second, when relatedness extends to functions and activities

[1] There is an inherent tension between the theoretical ideas about intangible resources and our relatively limited ability to measure them. Thus, it may be difficult to identify what a particular chemical engineer knows, but classifying an individual as a chemical engineer helps define what he or she is likely to be able to do.

[2] The case of Du Pont starkly illustrates this point. After the First World War, Du Pont had huge excess capacity in smokeless powder facilities. When considering alternative diversification outlets, physical excess capacity played an important role in the initial discussions. Only later did Du Pont's management start looking at the firm more broadly, and it then considered industries that built on Du Pont's knowledge of chemistry as well as in sales and other areas (Chandler, 1962: 84–85).

other than production, each base may identify interrelationships in distinct sets of functions. For example, the skill base of relatedness may identify similarity in research or marketing (where physical bases are less pronounced), whereas the physical base of relatedness may identify similarity in procurement (i.e., raw materials). Thus, each base may point to different interrelationships within production and the value chain as a whole.

The performance benefits of the physical base of relatedness, though primarily associated with cost reduction stemming from economies of scope (e.g., shared manufacturing facilities) (Teece, 1982), are also derived from economies of scale through better capacity utilization of physical resources (e.g., joint production of components) (Porter, 1985). Similar economies arise from human skill relatedness although they may take a different form. Individual skill resources (e.g., marketing), as well as skill *combinations* (e.g., marketing and design skills in the product development process) can be shared and transferred within a firm. These combinations are tied together through routines and work habits and are integrated by the firm's internal codes (Arrow, 1974), formal systems, and culture.

A particular attribute of human skill relatedness is the learning that occurs through continuous two-way transfers of knowledge and ideas between related lines of business. This learning can result in innovation and increased knowledge in each line of business and in gains through both cost reduction and increased differentiation and sales. Diversification is favored over market transactions because the innovations and lessons are retained within the firm and can be used for future purposes. This 'dynamic reciprocity' quality of relatedness is more directly associated with human learning and knowledge than with physical artifacts.

Each base implicitly highlights a distinct view of firms, production, and diversification, and points to particular benefits associated with relatedness. Yet, the bases agree with regard to the expected positive benefits of related diversification. This leads, when considering our second research question, to the following hypothesis:

Hypothesis 1a: The level of related diversification as indicated by the physical base of relatedness will be positively associated with financial performance.

Hypothesis 1b: The level of related diversification as indicated by the skill base of relatedness will be positively associated with financial performance.

THE JOINT EFFECTS OF THE PHYSICAL AND SKILL BASES OF RELATEDNESS

The distinctions between the physical and skill bases of related diversification should not obscure their strong complementary nature. Physical resources like land, equipment, and semi-finished products, join human resources, primarily skills, as part of the collection of productive resources that constitute a firm (Penrose, 1959: 24) or an industry.

When the two bases of relatedness are combined, both their union and their intersection may be of importance. The union of the two bases implies that when they agree in identifying relatedness between two or more industries (lines of business), the underlying set of interrelationships between these industries may be broader than can be identified by each base alone. Each base thus extends the other. In addition, the physical and skill bases overlap and interact in several value-added activities. This interaction is most evident in the production process when some kind of information or knowledge is able to direct energy toward the transportation, transformation, or rearrangement of materials into final products. A car, for example, is produced when factories, machines, and assembly lines are used by a large number of human occupational 'species' like managers, foremen, assembly line workers and others (Boulding, 1978: 34). The interaction between the physical and skill aspects of production is institutionalized in organizational routines and procedures (Nelson and Winter, 1982). It also forms a cycle: human expertise husbands material artifacts, and additional human expertise is created through the translation of the interaction into symbolic representation (Barley, 1992; Chi, Glaser, and Farr, 1988). Therefore, learning increases the services derived both from the employees and from the material resources (Penrose, 1959: 76–78).

Combination of the physical and skill bases may affect performance in two ways. First, more potential interrelationships are identified, and thus the range of potential benefits is extended. Second, where the two bases coexist and interact, specifically in the production process, their potential benefits are complementary. For example, transferring or sharing a routine or activity that ties together physical resources (e.g., common components) and skill resources (e.g., precision production skills) can generate both cost and learning benefits. Since knowledge is often accumulated through a learning-by-doing process, transferring physical artifacts may not be valuable unless it is accompanied by the associated skills and expertise (Teece, 1982). Additionally, the benefits associated with the transfer or sharing of one of the two bases often lead to the transfer or sharing, and benefits, of the other. For example, transferring production skills from one line of business to another may initially benefit the firm by spreading costs and enhancing learning and innovation. This action may then lead to an understanding of new sources of cost savings in physical resources, such as equipment. So we propose a second hypothesis:

> *Hypothesis 2: The level of related diversification indicated by a combination of both the physical and skill dimensions will be positively associated with financial performance.*

METHOD

Manufacturing focus

Our study focuses on the manufacturing sector (i.e., SIC codes 20 to 39). This choice is motivated by two observations derived from previous research and from our own experience with the data. First, vertical integration across sectors (e.g., manufacturing and retail) is widespread (e.g., Gort, 1962). Since industries in sectors representing sequential value-added activities such as manufacturing and retail are classified in the SIC system into different industry groups (i.e., 2-digit SIC), this can lead to two methodological problems: (1) the risk of confusing cross-sector vertical integration with diversification and thus overestimating diversification; and (2) the risk of identifying cross-sector vertical integration incorrectly as unrelated diversification and thereby underestimating relatedness. The second observation suggests that in order for the occupational skill profile (used to identify similarity of industries) to more accurately classify industries into distinct industry groups, it needs to be refined in sector-specific occupations (e.g., a variety of engineering occupations within manufacturing) more than in general occupations (e.g., service). The focus on manufacturing industries (or lines of business), manufacturing-specific occupations, and the diversification of manufacturing firms within this sector, allows all the above considerations to be dealt with simultaneously. Thus the manufacturing focus provides an internal consistency among the methodological decisions that follow, and as a consequence increases the validity and relevance of the study.

Sample selection

To examine the diversification patterns of different firms we used the TRINET data set, which provides comprehensive data at the 3-digit SIC code level of detail about the different industries in which firms operate (see Davis and Duhaime, 1992, for additional description of the data base). The firms studied were identified by aggregating all the establishments that have the same parent company identifier. We considered only diversified firms (i.e., those operating in more than one 3-digit SIC code) that were based in manufacturing industries, and that were part of the *Fortune* 500 list for 1985. This choice also allowed better comparability to most previous diversification research. These requirements eliminated from consideration firms whose names did not appear on both the *Fortune* 500 and TRINET data bases (for example, firms that merged during 1985 and appeared as separate firms in one list and as a single firm on the other), and those that were identified as a manufacturing firm on one list, but in some other sector on the other list. A set of 316 *Fortune* 500 firms resulted.

To reduce the effects of diversification occurring in nonmanufacturing activities, and to make the study as self-contained as possible, we further selected only firms that had at least 90 percent of their sales in manufacturing—bringing our final sample to 158. This cut-off point was the median percentage in manufacturing sales for the 316 firms. Nonmanufacturing lines of business, which can be both unrelated or related (like retail outlets), accounted for at most 10 percent of total sales for each firm studied. Moreover, manufacturing firms could still have a very unrelated diversification within manufacturing industries (e.g., aircraft and bakery products).[3]

Skill base of relatedness

Using a skill-based approach, each industry was characterized by its underlying profile of specialties defined as the different types and extent of human skills required in the industry, as indicated by occupational distributions. Using cluster analysis, industries with similar skill profiles were grouped to form skill-related industry groups.

To the extent that the firm's sales in different lines of business are concentrated within skill-related industry groups, the firm's diversification is considered to be related.[4] Continuous measures of diversification, like the Entropy measure (e.g., Palepu, 1985) and the Herfindahl index (e.g., Montgomery, 1982), can then be used to assess the extent of a firm's total and related (within-industry-group) diversification.

The first step in building the skill-based classification is the construction of industry skill profiles. To measure human skills requirements, we used the Occupational Employment Survey (OES) conducted by the U.S. Department of Labor Statistics. The OES data set is highly compatible with the TRINET data set for 1985, is collected from individual establishments, and defines industries at the equivalent of 3-digit SIC code level of detail. The OES contains data about the percentage distribution of 480 occupations in all U.S. industries. The occupational employment ratios are an indicator of both the different *types* of human expertise needed in an industry and the *extent* to which they are required. The occupational ratios refer to the occupations in which employees are working rather than the occupation for which they were trained. They correspond to the theoretical construct of human skills or knowledge because they are based on similarity of skills related to data (e.g., synthesizing), people (e.g., mentoring) and things (e.g., setting up). The particular use of occupational profiles captures the interrelated nature of skills highlighted in the theoretical discussion.

To construct industry expertise profiles, the number of occupational measures had to be reduced to allow meaningful interpretation and to facilitate the data processing. This demand had to be balanced with the desire to include as many dimensions as possible in a clustering profile to avoid masking important differences between the cases clustered (Hambrick, 1984). Technical limitations in handling the massive amount of data put an upper bound on the number of occupations in the profiles. A factor analytical approach to data reduction was abandoned as it did not significantly reduce the number of variables. Instead, we adopted the OES classification at the Major Group level of detail. This approach had the advantage of using the existing structure of a highly developed classification scheme. All major groups of occupations—Management and Management Support, Professionals, Marketing and Sales, Administration, Service, and Production and Agriculture—were included in the profile. This assured that in each industry the occupational distribution summed to 100 percent, and thereby allowed industry profiles to be compared without losing information. To better discriminate among industries within manufacturing, major occupational groups that are primarily relevant to manufacturing such as professionals (e.g., engineering) were further differentiated (e.g., chemical engineers). The resulting profile which included 38 summary occupational variables represents a broad range of business functions and skills, and enabled a more refined clustering of skill-related manufacturing industries.

The raw scores (ratios) of the occupational variables were further standardized around their mean score across all manufacturing industries. Standardization of variables prior to the cluster procedure is recommended (Hambrick, 1984) and is particularly appropriate when using Euclidean

[3] Subsequent *t*-test analysis comparing the 158 firms studied with the 158 firms not studied (due to manufacturing sales below 90%), with regard to measures of relatedness *within manufacturing lines of business*, showed no significant (<0.05) difference for the skill or physical bases. The firms in our manufacturing-based sample were on average smaller in size (as measured by sales and employment), and operated in a smaller number of industries (manufacturing and nonmanufacturing) than the excluded firms. Since we were interested only in diversification and relatedness within manufacturing, the test result suggested that the study sample showed no systematic bias with regard to estimating relatedness.

[4] The standard assumption in studies using the SIC code to identify relatedness is that if the prevailing theory of diversification holds, a firm will diversify into a group of industries which require resources similar to their own. Thus, for both skill and physical base approaches to relatedness, the firm-specific profile of resources, while not observed, is inferred from the resource profile of the particular industry group in which the firm operates.

distance measures. This practice allows comparability between different industries and reduces the impact of outliers. Since weighting variables is highly subjective and is generally not recommended (Sneath and Sokal, 1973), we gave each variable equal weight. A drawback is that the resultant occupational profile does not capture specific skills such as skill in managing a cyclical business, and is not very effective in differentiating skills associated with marketing or with specific customers (e.g., defense). A summary distance measure between the resource profiles of each pair of industries was calculated using the Square Euclidean distance measure. The lower the measure, the more similar industries are in terms of their profiles, and the more likely they are to be clustered together. The calculation of the distance measure for each pair of industries results in an industry-by-industry similarity-in-skills matrix that serves as the input for the subsequent cluster analysis. Clustering industries by their profile similarity using Ward's method (SAS Institute, 1985) resulted in 8 industry clusters as determined by the pseudo t^2-statistic. The same number of clusters was found using the Centroid clustering method, and using the CCC and the pseudo F-tests.[5]

Table 1 summarizes the 38 types of skills used to create the industry-by-industry similarity-in-skills matrix subsequently used to cluster the industries in the manufacturing sector. It groups each occupational variable by its Major Group affiliation, and provides its mean and standard deviation. It further details the distribution of the standardized occupational variables in each of the 8 skill-related industry groups identified in the cluster analysis. Industries in each of the skill clusters are similar to one another with regard to the intensity by which certain occupations are required (as indicated by standard deviations from the mean in manufacturing). Thus, industries (lines of business) such as Printing and Books, included in cluster 8, are characterized by higher intensity of Marketing and Sales occupations relative to other manufacturing industries. This is indicated by the relatively high standardized score (3.39 standard deviations) of this occupational category for cluster 8. By looking at the mean (3.21) and standard deviation (2.67) of this particular occupation at the left side of the table one can readily determine that the actual intensity of this occupational skill is, on the average, 12.26 percent ($3.21 + 3.39 * 2.67$) of total employment for industries in this cluster. The table also can be used to map the industry clusters in which a specific occupation is more prevalent (e.g., Mechanical engineers are prevalent in industries in cluster 6).

[5] An additional analysis of variance (MANOVA) test for firm sales and related diversification measures for firms whose primary industry was located in each of the clusters showed significant ($p < 0.001$) differences between the clusters along these variables. The existence of cluster differences in important firm variables provides additional support for the robustness of the cluster solution.

Physical base of relatedness

Physical-base relatedness is determined from the SIC code. The SIC is a hierarchical system which uses survey data collected at individual establishments (defined as economic units, generally at a single physical location) to categorize industries at the 2-, 3- or 4-digit level of detail. Examples of 2- and 3-digit SIC codes may be found in Table 2. Diversification researchers (e.g., Montgomery, 1982; Palepu, 1985) have identified relatedness as the extent to which a firm's sales in different lines of business (usually defined at the 4-digit or 3-digit SIC level) are concentrated within a more aggregated industry group (usually 2-digit SIC code), rather than across industry groups. Although Rumelt's (1974) landmark study did not use SIC measures of relatedness, the use of concentration of the firm's sales within the same industry group is often assumed to correspond roughly to Rumelt's related diversified categories (Amit and Livnat, 1988).

The main criterion for classifying industries as related is the physical attributes of the product (e.g., raw materials used, plant and physical processes) (Gort, 1962; *Standard Industrial Classification Manual*, 1987), rather than product substitution as is generally assumed by researchers (Hay and Morris, 1985: 110). SIC-based measures have been criticized for the inconsistent criteria used to classify and to assess the distance between industries, and for the lack of consideration of a firm's unique history and strategy (e.g., Montgomery, 1982; Rumelt, 1974). Yet they demonstrate construct validity and are usually considered replicable, easy to use, and more objective than categorical, researcher-defined diversification measures (e.g., Hoskisson *et al*., 1993; Montgomery, 1982; Palepu, 1985).

Table 1. Types of skills in manufacturing and in the skill-related clusters represented by occupational measures

			Industry clusters[b]							
Skills	Mean[a]	S.D.	1	2	3	4	5	6	7	8
Top Management	2.81	1.34	0.16	−0.15	0.11	0.02	−0.38	−1.41	0.18	1.38
Financial Managers	0.36	0.17	−2.06	−0.27	−0.99	0.10	0.95	0.16	1.38	−0.04
Marketing Adv. Pr.	0.41	0.26	−1.58	−0.31	−0.97	0.09	0.92	−0.03	0.99	1.32
Human Resources	0.23	0.11	−2.15	−0.12	−0.93	0.10	0.68	0.08	1.31	−0.64
Purchasing Managers	0.15	0.07	−2.01	−0.28	−0.87	0.34	1.01	1.46	0.73	−0.95
All Other Managers	2.01	1.22	−1.18	−0.40	−0.72	−0.21	1.60	3.01	0.88	0.63
Management Support	2.07	1.38	−1.08	−0.35	−0.90	0.04	1.29	4.06	0.81	−0.60
Aeronautic. Engineers	0.07	0.50	−0.15	−0.15	−0.15	−0.12	−0.06	6.14	−0.15	−0.15
Chemical Engineers	0.23	0.58	−0.39	−0.24	−0.39	−0.32	−0.12	−0.10	2.21	−0.39
Electrical Engineers	0.74	1.73	−0.43	−0.38	−0.43	−0.06	2.71	1.58	−0.10	−0.43
Mechanical Engineers	0.69	0.73	−0.93	−0.53	−0.83	0.69	0.70	2.94	0.28	−0.92
Other Engineers	1.02	1.75	−0.58	−0.29	−0.47	0.13	0.56	5.11	0.06	−0.57
Life Scientists	0.09	0.47	0.00	−0.08	−0.17	−0.19	−0.02	−0.19	1.00	−0.12
Physical Scientists	0.41	0.91	−0.45	−0.18	−0.43	−0.35	−0.17	−0.24	2.28	−0.43
Other Natural Scientists	0.30	0.34	−0.88	−0.51	−0.68	−0.03	1.30	2.38	0.99	0.54
Soc. Science & Prof.	0.87	2.86	−0.30	−0.27	−0.17	−0.19	−0.06	0.11	−0.14	4.46
Technicians	2.84	2.61	−1.06	−0.54	−0.84	0.01	2.20	1.88	1.07	−0.50
Marketing and Sales	3.21	2.67	−1.15	−0.09	−0.19	−0.22	−0.07	−1.06	0.15	3.39
Admin. Support	12.19	5.69	−1.33	−0.52	−0.22	−0.12	0.62	0.18	0.36	3.58
Service Occupations	1.79	0.77	−1.48	0.38	−0.37	−0.09	−0.43	−0.02	0.38	−0.61
Superv. Blue Collar	4.46	1.33	−2.33	0.55	−0.39	−0.08	−0.84	−1.22	0.94	1.96
Construct. & Extract.	1.71	3.11	−0.50	0.36	−0.29	−0.14	−0.41	−0.04	0.28	−0.50
Mechanics & Install.	4.47	2.72	0.11	0.88	−0.66	−0.40	−0.81	−0.29	0.63	−1.41
Precision Metal Work.	3.31	4.76	−0.70	−0.30	−0.60	0.94	−0.05	0.39	−0.43	−0.68
Inspectors & Graders	2.88	2.14	−1.26	0.06	−0.29	0.24	0.81	0.44	−0.39	−1.24
Other Precis. Prod.	2.77	4.63	−0.60	−0.13	1.58	−0.49	−0.15	−0.51	−0.58	0.47
Machine Tool Cutting	4.24	5.93	−0.71	−0.35	−0.50	1.14	−0.31	0.02	−0.68	−0.71
Metal & Plastic Work.	2.28	4.19	−0.54	0.26	−0.43	0.39	−0.37	−0.33	−0.54	−0.54
Printing Workers	1.59	5.25	−0.30	−0.15	0.77	−0.27	−0.28	−0.30	−0.30	1.63
Textile & Rltd. Work	3.31	10.87	−0.30	−0.10	1.09	−0.28	−0.28	−0.30	−0.17	−0.30
Other Machine Setting	9.48	8.49	−1.07	0.56	0.17	−0.54	−0.65	−0.86	0.68	−1.05
Precision Assemblers	1.34	2.51	−0.54	−0.52	−0.54	0.49	2.03	1.27	−0.39	−0.54
Other Assemblers	9.88	8.87	−1.10	−0.32	0.05	0.78	0.53	−0.63	−0.89	−1.02
Plant and Systems	0.68	2.14	−0.32	−0.12	−0.30	−0.28	−0.29	−0.21	1.76	−0.32
Material Moving	2.19	1.88	0.54	0.87	−0.51	−0.26	−1.02	−0.98	0.12	−0.89
Trnsprt. & M. Moving	2.21	4.48	2.97	0.55	−0.20	−0.37	−0.46	−0.39	−0.16	−0.02
Helpers and Laborers	8.46	5.63	−1.03	0.97	0.41	−0.57	−1.03	−1.29	−0.49	−0.63
Agri. Forest. Fishing	0.88	6.33	9.60	−0.05	−0.10	−0.14	−0.14	−0.14	−0.11	−0.14

[a]Percentage of employees in each occupation across all U.S. manufacturing industries.
[b]The entries for each cluster indicate standard deviations from the mean occupational employment in all manufacturing industries.

Identifying relatedness by the skill and physical bases

The theoretical discussion has highlighted the implications of relying on a single base to identify relatedness. The differences between the physical and skill aspects of production suggest that industries identified as related on one dimension may not be as related on the other. Each base highlights distinct interrelationships in production and other value activities. At the same time, the complementary nature of the two bases, particularly in the transformation process, leads us to expect that the two bases will agree to some extent when it comes to determining relatedness of industries (lines of business). This also implies some agreement in the ways both potential competitors and diversification opportunities are identified.

The principles by which each of the two classifications is constructed can give us a more specific idea about the conditions under which they are likely to agree. The one system uses skill profiles to group industries that require similar production skills, scientific and engineering know-how, administration, and to a lesser extent, service and marketing skills. The other classification captures similarity in raw materials, physical production processes, and end use.

Consequently, the two systems will agree that industries are related when they employ similar production technology; they require similar skills and use similar physical processes. The classifications will disagree when the grouping is based on an aspect that is specific to one system. Industries will be related only on the physical dimension when the similarity is in raw materials or end use, but not in physical processes.

This occurs when a single raw material is transformed by different processes, requiring distinct sets of skills, and when products are close substitutes but are produced by different processes. Conversely, industries will be related only on the skill base when they demand similar production skills, but use different raw materials, and produce items with different end-uses, or where they make use of knowledge, such as engineering and marketing skills, that may be applied to disparate materials.

Measures of level of relatedness

To measure the extent of a firm's within-group (related) diversification, we used the Entropy measure of diversification (Amit and Livnat, 1988; Hall and St. John, 1994; Palepu, 1985). The definitions and details of the measure are given in Palepu (1985). This measure was chosen because it provides indices for both within- and between-group diversification, because it is considered to be more objective than categorical researcher-defined diversification measures, it is simple to calculate, and it has been shown to have a high degree of construct validity (Hoskisson *et al.*, 1993).

The Entropy measure uses only sales from manufacturing lines of business (defined at the 3-digit SIC level) in its computation. For each of the 158 diversified firms, lines of business belonging to the same industry group were given the same industry group identification. The less a firm's sales were dispersed across different industry groups, the higher was the related component of the Entropy measure. The number and types of industries in which firms are diversified and the distribution of firms' sales across these industries are the same regardless of the relatedness base used. However, the definition of industry groups varies with the relatedness measure computed: For the physical base, industry groups were defined by the 2-digit SIC (e.g., Palepu, 1985); for the skill-base, industry groups were defined by groups of similar skills revealed in the cluster analysis.

The ratio of related-to-total diversification indicates the extent to which a firm's diversification is related (e.g., Amit and Livnat, 1988). We used three measures of this ratio. RATIO (Physical) defines related diversification as diversification within 2-digit SIC product groups. RATIO (Skill) defines related diversification as diversification within skill groups revealed by the cluster analyses. RATIO (Joint) is a combined measure defined as the product of the first two measures. RATIO (Joint) has high values when firm-related diversification is high on both the physical and skill bases of relatedness and low when both have low values.[6]

Performance measures

To increase the criterion validity of our measures (Hoskisson *et al*., 1993), we used four measures representing both accounting and market-based indicators of performance. We computed ROA (return on assets) and ROS (return on sales), MBOOK (market-to-book ratio), and Jensen's alpha (ALPHA). The first three measures were taken from the COMPUSTAT files and Jensen's alpha was computed using the Center for Research in Security Prices (CRSP) data. A definition of each performance measure is provided in the Appendix.

For each firm we computed ROA and ROS

[6] High scores on both independent relatedness measures mean that they both view the *firm*'s various lines of business as being related—the firm's sales tend to be more concentrated within groups of similar industries rather than spread across different industry groups. By contrast, the agreement between the two classifications (Q1) indicates the extent to which both view the *same industries (lines of business)* as related. Although agreement between the classifications can contribute to high joint relatedness scores of firm diversification, these scores ultimately reflect the way a firm's lines of business are spread or its corporate strategy.

and averaged these measures for 1985–87 so as to reduce the effects of unusually good or bad years. Using ROS allows comparison with several other diversification studies that used it either alone, or jointly with the Entropy measure (e.g., Palepu, 1985). The measure is less sensitive to firms capital structure than ROA. The main advantage of ROA is its use in a large number of diversification studies (e.g., Bettis, 1981; Bettis and Hall, 1982; Mischel and Hambrick, 1992), and its more frequent use by managers. A limitation of ROA compared with ROS is that ROA is more indicative of returns from physical assets than from skills.

Next, we computed firm's ratio of market value of equity to its book value (Amit and Livnat, 1988; Nayyar, 1992b). Although there are important differences between the two measures, the market-to-book ratio measure is considered an acceptable proxy to Tobin's *Q*. Tobin's *Q* (Lindenberg and Ross, 1981) incorporates a systematic risk adjustment, imputes equilibrium returns, and minimizes distortions due to tax laws and accounting conventions (Wernerfelt and Montgomery, 1988).

Finally, we assessed firm performance relative to the stock market average by computing Jensen's alpha (Hoskisson *et al.*, 1993; Nayyar, 1992b), which measures firm performance against a portfolio with similar market risk. It is obtained by estimating the intercept in a regression of firm returns on market returns (CRSP equally weighted index with distributions), both computed in excess of the risk-free rate. As a measure based on the stock market, Jensen's alpha does not require further adjustment for a firm's participation in several industries each with different profitability potential.

Industry control variables

To control where necessary for industry structure effects on performance, we used industry dummy variables for the firm's primary industry defined at the 2-digit SIC level. This practice has been used in other diversification studies (e.g., Grant and Jammine, 1988) and is one of the recommended methods to control for industry effects (Dess, Ireland, and Hitt, 1990). The control is especially good in our sample as, on average, the firm's primary 2-digit SIC code accounted for 72 percent of the firm's total manufacturing sales (65% of total sales). A limitation of this control method is that the large number of industry dummies reduces the number of degrees of freedom for estimation purposes. We deal with this limitation in the analysis. The designated industry dummy variables, PRIME20 to PRIME39, indicate the category of a firm's primary industry, from SIC 20 to SIC 39.

ANALYSES AND RESULTS

Identifying relatedness (Q1)

We first compare the two bases of relatedness as alternative ways of determining relatedness between industries (lines of business).

Table 2 lists each of the 96 manufacturing industries together with its physical (2-digit SIC) industry group and skill-related industry cluster. Strong agreement emerges in Apparel (SIC 23), Furniture and Fixtures (SIC 25), Paper (SIC 26), Chemicals (SIC 28), Leather (SIC 31), Stone, Clay and Glass (SIC 32), Primary Metals (SIC 33), and Misc. Manufacturing (SIC 39) and to a lesser extent in industry groups Food (SIC 20), Industrial Machinery (SIC 35), and Electronics (SIC 36). The significance of the chi-square test and the high association measures reported at the bottom of the table provide additional evidence of an association between the two classifications.

On the other hand, strong disagreement appears in Printing and Publishing (SIC 27), Lumber and Wood (SIC 24), Rubber (SIC 30), Petroleum (SIC 29), Fabricated Metals (SIC 34), Instruments (SIC 38), and Transportation Equipment (SIC 37). Tables 1 and 2 also reveal interesting differences between the bases with regard to what industries they consider to be related. For example, industries that are usually considered unrelated because they are in different 2-digit SIC product groups are indeed related from a skill perspective. Sharing skill cluster 2, Tobacco (SIC 210) and Beverages (SIC 208) have a high requirement for helpers and laborers, materials moving, mechanics, and machine-setting skills.[7]

[7] The diversification of tobacco firms in the 1970s into beverages provides some face validity to this observation. The relatedness in the marketing of packaged consumer goods suggested by the conventional interpretation of these moves is different from the production relatedness suggested here.

Table 2. Cross-tabulation of manufacturing industries (3-digit SIC code) in physical-based groups (2-digit SIC) and skill-based groups

2-Digit SIC	3-Digit SIC	Industry title	Skill group	2-Digit SIC	3-Digit SIC	Industry title	Skill group
20-	201	Meat Products	3	28-	283	Drugs	7
Food	202	Dairy Products	2	Chemicals	284	Soap	7
	203	Preserved Fruits	2		285	Paints	7
	204	Grain Mill Products	2		286	Indus. Organic Chem.	7
	205	Bakery Products	2		287	Agri. Chemicals	7
	206	Sugar	2	29-	289	Misc. Chemicals	7
	208	Beverages	2	Petroleum	291	Petr. Refining	7
21-	209	Misc. Food	2	& Coal	295	Misc. Petr.	2
Tobacco	210	Tobacco	2	30-	301	Tires	7
22-	221	Weaving	3	Rubber	302	Rubber Products	2
Textile	225	Knitting Mills	3	31-	307	Misc. Plastic Prod.	2
	227	Floor Covering	2	Leather	311	Footwear	3
	229	Misc. Textile	2	32-	313	Luggage	3
23-	231	Apparel	3	Stone,	321	Flat Glass	2
Apparel	239	Misc. Apparel	3	Clay	322	Glass & Glassware	2
24-	241	Logging	1	& Glass	327	Concrete & Gypsum	2
Lumber	242	Sawmills	2		329	Other Clay	2
and Wood	243	Millwork	3		331	Blast Furnaces	2
	244	Wood Containers	3	33-	332	Iron & Steel	2
25-	245	Wood Building	2	Primary	335	Nonferrous Rolling	2
Furniture	251	Household Furniture	3	Metals	336	Nonferrous Foundries	2
and Fixtures	252	Partitions	3		339	Other Primary Metals	2
26-	254	Office Furniture	3		341	Metal Cans	2
Paper	261	Pulp & Paper Mills	2	34-	342	Cutlery	4
	264	Converted Paper	2	Fabricated	343	Plumbing & Heating	4
	265	Paperboard	2	Metals	344	Fabric. Struc. Meta.	4
	271	Newspapers	8		345	Screw Machine Prod.	4
27-	272	Periodicals	8		347	Metal Coating	2
Printing	273	Books	8		348	Ordnance	4
and	274	Misc. Publishing	8		349	Misc. Fabric. Metals	4
Publishing	275	Commercial Printing	3	35-	351	Engines & Turbines	4
	278	Blankbooks	3	Industrial	352	Farm & Garden Mach.	4
	279	All Other Printing	3	Machinery/	353	Construction Mach.	4
	281	Indus. Inorg. Chem.	7	Equipment	354	Metalworking Mach.	4
	282	Plastics Materials	7		355	Special Indus. Mach.	4
					356	General Indus. Mach.	4

Table 2. Continued

2-Digit SIC	3-Digit SIC	Industry title	Skill group	2-Digit SIC	3-Digit SIC	Industry title	Skill group
	357	Office & Comput. Eq.	5	37-	372	Aircraft and Parts	6
	358	Refrigeration	4	Transport.	373	Ship & Boats	2
	359	Misc. Indus. Mach.	4	Equipment	376	Guided Missiles	6
	361	Electric Distr. Eq.	4		379	All Other Trans.	4
	362	Electric Ind. App.	4		381	Engineering Instru.	5
36-	363	Household Appliances	4	38-	382	Measuring Devices	5
Electronic/	364	Elec. Lighting Eq.	4	Instruments	384	Medical Instru.	5
Electric	365	Elec. Household Eq.	4		386	Photographic Equip.	7
Equipment	366	Communic. Equip.	5		389	All Other Instr.	5
	367	Elec. Components	5	39-	391	Jewelry	4
	369	Misc. Elect. Equip.	4	Misc.	393	Toys & Sporting	4
	371	Motor Vehicles	4	Manufact.	394	Other Manufacturing	4

Chi-square significance level = 0.00000
Measures of association: Cramer's V = 0.73120 (out of 1); lambda = 0.48052 (out of 1).

A contrary example is industries that are usually considered related because they are in the same 2-digit physical product group, but are not at all similar from a skills standpoint. Tires (SIC 301) and Rubber (SIC 302) are in the same physical product group (SIC 30) because they use similar raw materials. However, Tires are in skill cluster 7 along with other chemical industries that utilize engineering and science skills and share process production, while rubber is in skill cluster 2, where very different skills are required.

These patterns of agreement and disagreement between the classifications generally confirm our expectations. Industries are considered related by the physical base only in some cases of within-sector vertical integration such as in Lumber and Wood (SIC 24), Rubber (SIC 30), Petroleum (SIC 29), and Fabricated Metals (SIC 34)—all examples of industries that use similar raw materials but complementary production processes. Alternatively, physical relatedness occurs when products are considered as close end use substitutes but their underlying transformation processes are different, as in Instruments and Transportation Equipment. Finally, as in the case of Printing and Publishing, industries may be grouped based on the basis of similar physical production processes, although they require different skills in administration, production, and marketing. By contrast, industries identified as skill-related only share similar production, engineering, administration, and marketing and service skills, but not raw materials, end use, or physical aspects of production. For example, similar production skills (cluster 2) but different raw materials are employed in Food and Tobacco, and similar engineering and production skills are employed in Photographic Equipment and Tires (cluster 7).

When we look at agreement between the classifications we see that it is not distributed uniformly across the full range of manufacturing industries. Specifically, when the two classifications agree, two effects seem to operate: first, a *complementarity* effect—they agree on similarity in production as indicated by both skills and physical characteristics; and second, an *extension* effect—the underlying relatedness is broader than indicated by each base alone and encompasses similarity in production, science and engineering, administration, marketing and service, and at times raw materials and end use. Thus, for example, in Chemicals, industries share physical production processes and skills (complementarity effect), and are also similar in raw materials and in other functions such as science and engineering (extension effect).

The above comparison shows the conditions and extent to which the two categorizations agree as they identify relatedness. It demonstrates how our concept of relatedness depends on which base we use, and lends support to our general expectations regarding the first research question.

Relationship between relatedness and performance (Q2)

Table 3 provides descriptive statistics and correlations for the variables used in the related diversification and performance analyses below. The actual extent of related diversification indicated by the two approaches is shown in the measures RATIO (Physical) and RATIO (Skill) in Table 3. The skill-related ratio (0.58) means that, on average, 58 percent of total firm diversification within the manufacturing sector is related from a skill standpoint. It is significantly higher ($p < 0.001$) than the physical-relatedness measure (0.42).

Turning to the performance measures, we see that ROS and ROA, the two accounting return measures, are highly correlated (0.882) with one another, and with the market-to-book measure. Thus, although conceptually different, the two accounting measures empirically cluster with the market-to-book measure. The Jensen's alpha measure, uncorrelated with the three other performance measures, forms a separate cluster. The performance variables are not highly correlated with RATIO (Physical) or RATIO (Skill), but both accounting measures are correlated with the interactive related measure RATIO (Joint).

Tables 4 and 5 report the effects of firm-related diversification on ROA (Table 4), and on market-to-book ratio (Table 5). They contain four columns each reporting a different regression model.[8]

[8] To detect a potential problem of multicollinearity, we examined the Variance Inflation Factor (VIF), where values greater than 5 indicate a potential problem. The VIF for RATIO (Physical) ranged between 3.46 and 4.4; for RATIO (Skill) between 2.46 and 3.33; and for RATIO (Joint) from 5.49 to 7.05. The relatively high value for RATIO (Joint) was expected given that the variable was constructed by multiplying the other two RATIO variables. We also conducted several additional tests recommended in the literature (e.g., Maddalla, 1988): testing the effects on the coefficients when

Table 3. Means, standard deviations, and correlations[a]

	Mean	S.D.	1	2	3	4	5	6
1. RATIO (PHYSICAL)[b]	0.42	0.30						
2. RATIO (SKILL)	0.58	0.29	0.167*					
3. RATIO (JOINT)	0.26	0.26	0.763***	0.614**				
4. ROA	5.85	4.37	0.059	0.032	0.165*			
5. ROS	4.74	4.00	0.135	0.060	0.228**	0.882**		
6. MBOOK	2.22	1.76	–0.05	–0.033	0.047	0.725**	0.655**	
7. (JENSEN) ALPHA	0.07	0.10	0.059	0.015	0.091	0.098	0.160	0.059

Significance levels: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

[a]For clarity, the descriptive statistics for the industry dummy variables are not shown. The number of observations for the measures are $N = 158$ for relatedness measures, $N = 147$ for accounting return measures, $N = 124$ for the market-to-book measure, and $N = 114$ for the Jensen's alpha measure.

[b]A *t*-test comparison of the related ratios RATIO (PHYSICAL) and RATIO (SKILL) showed the existence of a significant difference between the two at the 0.001 level.

Table 4. Regressions of firm performance upon firm-related diversification[a]

	Dependent variable: ROA			
Model: Explanatory variable	1. Reduced (with industry controls)[b]	2. Full (with industry controls)	3. Reduced (without industry controls)	4. Full (without industry controls)
Constant	4.454***	6.471***	5.323***	7.910***
	(1.115)	(1.439)	(0.895)	(1.181)
PRIME27	5.327*	4.732*	–	–
(Publishing)	(2.135)	(2.116)		
PRIME28	3.141*	2.812*	–	–
(Chemicals)	(1.345)	(1.330)		
PRIME35	–3.366*	–3.315*	–	–
(Equipment)	(1.553)	(1.527)		
RATIO	1.484	–2.303	0.791	–4.367*
(SKILL)	(1.39)	(2.147)	(1.216)	(1.906)
RATIO	–0.239	–4.525	0.325	–5.152*
(PHYSICAL)	(1.399)	(2.314)	(1.272)	(2.185)
RATIO	–	7.823*	–	10.131**
(JOINT)		(3.404)		(3.137)
F-Equation	1.612	1.847*	0.284	3.678*
F-Change		5.281*		10.428**
R^2	0.1943	0.2267	0.004	0.071
Adjusted R^2	0.0738	0.1040	–0.010	0.052
N	147	147	147	147

[a]Each entry contains the regression coefficient and its standard deviation (in parentheses). Significance levels are indicated by number of asterisks: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

[b]To control for potential industry influences, all available industry group (2-digit SIC) variables (e.g., PRIME27) are entered in Models 1 and 2. For brevity, only significant (<0.05) industry group dummy variables are presented. The baseline is industry group 39 (Misc. Manufacturing).

a few observations were dropped or when an independent variable was added or excluded, and examining the Conditional Index. These tests consistently suggested that although multicollinearity did exist, it did not create a serious estimation problem requiring remedial action.

Model 1, a reduced model, reports the hierarchical regression analysis used to test the independent effects of the physical and skill bases of related diversification on performance (Hypothesis 1). Model 2 reports the results of the hierarchical regression including the interaction independent

Table 5. Regressions of firm performance upon firm-related diversification[a]

Model: Explanatory variables	Dependent variable: MARKET TO BOOK RATIO 1. Reduced (with industry controls)[b]	2. Full (with industry controls)	3. Reduced (without industry controls)	4. Full (without industry controls)
Constant	1.384**	2.089***	2.421***	3.298***
	(0.489)	(0.599)	(0.380)	(0.497)
PRIME20	1.719*	1.609*	–	–
(Food)	(0.664)	(0.657)		
PRIME27	3.118***	2.91**	–	–
(Publish.)	(0.8724)	(0.867)		
PRIME28	2.095***	1.967**	–	–
(Chemicals)	(0.603)	(0.598)		
PRIME30	2.744*	2.727*	–	–
(Rubber)	(1.248)	(1.231)		
PRIME36	1.353*	1.493**	–	–
(Electron.)	(0.560)	(0.557)		
RATIO	0.226	–1.107	–0.138	–0.172*
(SKILL)	(0.580)	(0.883)	(0.527)	(0.789)
RATIO	–0.861	–2.372*	–0.279	–2.292*
(PHYS.)	(0.584)	(0.955)	(0.507)	(0.905)
RATIO	–	2.752*	–	3.409**
(JOINT)		(1.389)		(1.284)
F-Equation	1.613	1.772*	0.216	2.500
F-Change		3.927*		7.046**
R^2	0.228	0.256	0.003	0.059
Adjusted R^2	0.086	0.111	–0.013	0.035
N	124	124	124	124

[a]Each entry contains the regression coefficient and its standard deviation (in parentheses). Significance levels are indicated by number of asterisks: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.
[b]To control for potential industry influences, all available industry group (2-digit SIC) variables (e.g., PRIME27) are entered in Models 1 and 2. For brevity, only significant (<0.05) industry group dummy variables are presented. The baseline is industry group 39 (Misc. Manufacturing).

variable RATIO (Joint). By testing the added contribution of this full model over the reduced model, we examined the effects of combining the two bases of relatedness (Hypothesis 2). All industry control variables were entered in both Model 1 and Model 2 to test the effects of all variables of interest. The relatively large number of industry control variables markedly reduced the number of degrees of freedom for the estimation of the regression coefficients. Therefore, we repeated in Model 3 and Model 4 of each table the analyses conducted to test Hypotheses 1 and 2 (i.e., Models 1 and 2)—this time without including the industry control variables.

Table 4 reports the regressions of firm performance, measured by ROA, upon firm-related diversification. Besides the use of the measure by managers, the analyses for ROA contain a much larger number of valid observations than the subsequent analyses and thus provide a more robust model for estimation. The results for the regressions of the ROS measure turned out to be almost identical and therefore are not presented.

The insignificant *F*-statistic in Model 1 of Table 4 shows that the explanatory variables included in the regression do not explain much of the observed variance in firm performance. In particular RATIO (SKILL) and RATIO (PHYSICAL) measures of relatedness are not significant. The larger, and significant effects on performance are due to the positive industry effects of Chemicals and Allied Products (SIC 28) and of Printing and Publishing (SIC 27), and the negative effects of Industrial Machinery and Equipment (SIC 35) relative to the omitted dummy variable (Misc. Manufacturing, SIC 39).

The high performance of Chemical and Allied firms is consistent with earlier findings (Bettis and Hall, 1982). The results of this analysis for testing Hypothesis 1 provide *no support* for the expected relationship between physical relatedness and performance or between skill-based relatedness and performance.

Model 2 of Table 4, which includes the combined relatedness measure RATIO (JOINT), has better explanatory power than Model 1, and the *F*-statistic is now significant. As in Model 1, the RATIO (SKILL) and RATIO (PHYSICAL) variables are not significant. Important for our purposes is the positive and significant coefficient of the combined term RATIO (JOINT) and, even more so, the significance of the *F*-Change statistic indicating the added explanation of the full model in Model 2 above the reduced model in Model 1.[9] The significance of the interaction term and of the *F*-Change indicates that there is a significant and positive effect of the joint relatedness measure on ROA beyond industry effects, and that the added contribution of the interaction in explaining performance is significant. These results strongly support Hypothesis 2. Related diversification as expressed by a combination of both the skill and physical bases of relatedness is positively and significantly associated with financial performance.

Models 3 and 4 of Table 4 generally reinforce the results of Models 1 and 2 and provide additional support for Hypothesis 2. The R^2 is much smaller than in the previous models. The *F*-statistic and *F*-Change statistic in Model 4 are significant. Again as in Model 2, the RATIO (JOINT) variable coefficient is significant and its coefficient indicates a positive effect on performance. The independent effects of RATIO (SKILL) and RATIO (PHYSICAL) are not significant in Model 3. However, due to the introduction of the interactive term they become significant and negative in Model 4. The coefficients for the independent variables represent the rate of increase in performance with ROS when ROA equals zero, and with ROA when ROS equals zero (Southwood, 1978: 1164). Therefore, for the subset of firms scoring zero on physical relatedness (RATIO (PHYSICAL) = 0), performance decreases on average when their skill relatedness scores increase. Similarly, for the subset of firms scoring zero on skill relatedness (RATIO (SKILL) = 0) performance decreases on average when their physical relatedness scores increase. The results for these two subsets of firms contradict our prediction for Hypothesis 1.

Table 5 reports the results of regressing the market-to-book ratio measure (a hybrid of accounting and market-based measures of performance) upon related diversification. The results are similar to those obtained in the previous analyses. In additional analyses, not shown, we regressed Jensen's alpha—a stock market measure of performance—upon related diversification. Neither of the relatedness ratios, RATIO (SKILL), and RATIO (PHYSICAL), nor their interaction RATIO (JOINT), was statistically significant. Thus, the level of related diversification was not significantly associated with greater-than-risk-free returns. This means that, on average, the returns from holding a firm's stock were the same as those expected from holding a portfolio with similar market risk. These results provide *no support* for Hypothesis 1 or 2.

DISCUSSION

The findings refine our understanding of relatedness as a multidimensional concept. They suggest that to have a more complete assessment of firm-level relatedness and its repercussions on performance one needs to consider a matrix of interrelationships across lines of business, activities (e.g., production and marketing), and resources (e.g., skills and physical). The study illustrates that the use of more than one classification to identify relatedness exposes the limitations and strengths of each base, provides a more refined definition of relatedness, and reveals its potential benefits more fully.

The findings regarding the identification of relatedness (Q1) support our contention that the physical aspects of production and diversification and common bodies of knowledge are distinct yet complementary bases for relatedness. Both our qualitative and quantitative analyses show that the two alternative partitions of the manufacturing sector exhibit a high, though not uniform, degree of agreement. The general pattern emerging from

[9] An indication of the interaction effect is given by the significance of the added contribution as indicated by the *F*-Change statistic (Neter, Wasserman, and Kutner, 1988: 707–709).

the comparison is that the classifications agree when the underlying relatedness is in production and is extended to other interrelationships. Our analyses showed that industries or lines of business viewed as related from one standpoint can be viewed as unrelated from another—each base highlights a distinct set of interrelationships within production and the value chain as a whole.

Since our study examined each base independently, these findings are best appreciated when we compare them to previous research that used a single base of relatedness to study issues such as the direction of diversification (e.g., Chatterjee and Wernerfelt, 1991; Farjoun, 1994), or the relationship between related diversification and performance (e.g., Palepu, 1985). By using a single base of relatedness those studies identified only a subset of the potential relationships in production and in other value activities. The choice of a particular base might also have affected the way firms were categorized into related and unrelated diversification categories. These conclusions support previous observations that empirical results may be sensitive to different classification schemes (e.g., Ramanujam and Varadarajan, 1989; Seth, 1990). Particularly, they support the finding that the use of the physical classification tends to detect interrelationships in production better than in marketing and R&D (Davis and Duhaime, 1992: 521). The use of an additional classification extends the range of possible relationships identified.

Contrary to our expectations for Research Question 2 (Q2), the analyses for all performance measures showed that the skill and physical base approaches, when taken alone, had no significant effects on financial performance (Hypothesis 1). This lack of support for the value of corporate diversification strategy in boosting performance is in sharp contrast to the strong industry effects on firm performance that were found. Taken by itself—without considering the existence of multiple bases—the finding does not support the arguments for the independent benefits of skill-base relatedness. Furthermore, the finding of no significant effects for the physical base of relatedness provides additional support for previous diversification studies that did not find performance disparities between related and unrelated diversified firms (Amit and Livnat, 1988; Grant and Jammine, 1988).

The most revealing study findings are those associated with the joint effects of the two bases of relatedness on firm performance measures (Hypothesis 2). Although neither base by itself was associated with strong performance effects, when the diversification was related on *both* the physical base and the skill base, a strong effect of relatedness on performance emerged. These results did not hold for the market-based measure, suggesting, as in previous studies of diversification performance (e.g., Chatterjee and Blocher, 1992), that it captures a distinct dimension of financial performance. However, the findings of joint effects held, after controlling for industry effects, for all three other performance measures. The positive association with performance of the interaction of the two bases of relatedness strongly supports the arguments given here and by others (e.g., Boulding, 1978; Penrose, 1959) for the complementary benefits of the two bases (Hypothesis 2). It is also consistent with previous research emphasizing the importance of complementary assets (e.g., Teece, 1987), and extends previous explanations that primarily emphasized the benefits associated with relatedness in one key resource (e.g., Panzar and Willig, 1981; Teece, 1982). Although industry effects were large, the additional effect of joint relatedness on performance is strong and provides support for corporate strategy that builds on complementary bases of relatedness.

The finding of an interaction effect is consistent with the argument that the combination of the physical and skill bases affects performance in two ways: it extends the range of potential benefits provided by each base alone, and reinforces those benefits when the two bases agree. Related diversification that builds on both physical and skill relatedness allows firms to benefit from sharing and transferring skill and physical resources, and to take advantage of activities and routines in which these resources interact. Furthermore, for firms which are completely unrelated on one of the bases, relatedness on the other base may in fact be associated with decreased performance. This may occur, for example, when the cost of establishing and maintaining organizational mechanisms to exploit economies of scope outweighs the performance benefits associated with leveraging only one type of relatedness.

There are several implications for managers. Additional lenses extend the range of industries to consider for diversification—and also the range of potential competitors and partners. However, when it comes to the actual decision on diversification, a more conservative definition of relatedness—one that considers a combination of key bases—is important. Each classification provides an additional screening test for the related diversification decision. For firms already diversified, integrating across business units related in several activities, or in activities where skill and physical bases are highly complementary, may be most promising.

The fact that the skill and physical bases are complementary, and are only two among several important bases of relatedness, may affect the generalizability of the findings. It is important therefore to consider the effects of more than two key bases, of bases that are less complementary, and of the utilization of other important bases of relatedness such as information and technology. For example, in service industries, similarity in customer groups may be an important base of relatedness. Future research could cluster industries by using customer-group similarity profiles based on input–output tables (e.g., Lemelin, 1982). Future studies could also examine the effects of complementary resources by looking at single diversification moves as in Shelton (1988). It would also be worthwhile to consider the conditions under which organizational mechanisms used to create interrelationships decrease or nullify the potential advantages of relatedness.

In addition to developing and testing the theoretical implications of combining different dimensions of relatedness, future research can improve and extend the methods of this study. A limitation of both the physical and skills approaches to relatedness is the fact that they capture relatedness as viewed by external observers and not by insiders (Nayyar, 1992a; Prahalad and Bettis, 1986; Stimpert, 1992). Additionally, although our study carefully isolated the effects of cross-sector vertical integration, there is a need to better isolate the effects of within-sector vertical integration. The occupational measures we used were limited in that they did not capture other important kinds of skills such as social and political. Additional measures of performance that more directly examine the benefits of human learning and innovation could augment the financial peformance measures used. Finally, both the skill and physical bases of relatedness could benefit from firm data on specific resources (e.g., Hitt and Ireland, 1985).

The concept of relatedness essentially deals with relationships between activities or resources. Therefore, its significance goes far beyond the study of diversification and its consequences. A multidimensional view of relatedness can further our understanding of cooperation, competition, and—even more fundamentally—the underlying reasons for the existence of firms as value-creating institutions.

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APPENDIX: DEFINITIONS OF PERFORMANCE MEASURES

1. Return on Assets (ROA) = Net income divided by total assets, expressed as a percentage. Averaged across 1985–87.
2. Return on Sales (ROS) = Net income divided by net sales, expressed as a percentage. Averaged across 1985–87.
3. MBOOK = Market to Book value of equity = market value of equity at year-end divided by net worth at year-end. Averaged for 1985–87.
4. Jensen's alpha (ALPHA) = the intercept term in the following regression equation estimated using daily stock returns for 1985–87:

$$(R_{rt} - R_{ft}) = L_r + B_r(R_{mt} - R_{ft})$$

where R_{rt} = stock return on day t for firm r; R_{mt} = stock return on day t for a market portfolio; R_{ft} = risk-free rate of return computed as the daily return on a 12-month treasury bond for each month; B_r = systematic risk for firm r; and L_r = Jensen's alpha for firm r.