



Cornell University
ILR School

Cornell University ILR School
DigitalCommons@ILR

CAHRS Working Paper Series

Center for Advanced Human Resource Studies
(CAHRS)

September 2002

Strategic Knowledge Measurement and Management

John W. Boudreau
Cornell University

Follow this and additional works at: <http://digitalcommons.ilr.cornell.edu/cahrswp>

Thank you for downloading an article from DigitalCommons@ILR.

Support this valuable resource today!

This Article is brought to you for free and open access by the Center for Advanced Human Resource Studies (CAHRS) at DigitalCommons@ILR. It has been accepted for inclusion in CAHRS Working Paper Series by an authorized administrator of DigitalCommons@ILR. For more information, please contact hlmdigital@cornell.edu.

Strategic Knowledge Measurement and Management

Abstract

Knowledge and intellectual capital are now recognized as vital resources for organizational survival and competitive advantage. A vast array of knowledge measures has evolved, spanning many disciplines. This chapter reviews knowledge measures focusing on groups of individuals (such as teams, business and organizations), as they reflect the stock or flow of knowledge, as well as enabling processes that enhance knowledge stocks and flows. The chapter emphasizes the importance of organizational value chains, pivotal talent pools and the link between knowledge and competitive success, in understanding the significance of today's knowledge measures, and opportunities for future research and practice to enhance them.

Keywords

measurement, performance, HR, work, market, science, human capital, research, knowledge, intellectual capital, management

Comments

Suggested Citation

Boudreau, J. W. (2002). *Strategic knowledge measurement and management* (CAHRS Working Paper #02-17). Ithaca, NY: Cornell University, School of Industrial and Labor Relations, Center for Advanced Human Resource Studies.

<http://digitalcommons.ilr.cornell.edu/cahrswp/58>

WORKING PAPER SERIES

Strategic Knowledge Measurement and Management

John W. Boudreau

Working Paper 02-17



Strategic Knowledge Measurement and Management

Professor John W. Boudreau

Department of Human Resource Studies, ILR School
Director, Center for Advanced Human Resource Studies (CAHRS)
Cornell University
187 Ives Hall
Ithaca, New York 14853-3901
http://www.ilr.cornell.edu/CAHRS/boudreau_john.html
P: 607-255-9358
Voice-mail: 607-255-7785
F: 607-255-4953
jwb6@cornell.edu

September 24, 2002

<http://www.ilr.cornell.edu/cahrs>

This paper has not undergone formal review or approval of the faculty of the ILR School. It is intended to make results of Center research available to others interested in preliminary form to encourage discussion and suggestions.

Abstract

Knowledge and intellectual capital are now recognized as vital resources for organizational survival and competitive advantage. A vast array of knowledge measures has evolved, spanning many disciplines. This chapter reviews knowledge measures focusing on groups of individuals (such as teams, business and organizations), as they reflect the stock or flow of knowledge, as well as enabling processes that enhance knowledge stocks and flows. The chapter emphasizes the importance of organizational value chains, pivotal talent pools and the link between knowledge and competitive success, in understanding the significance of today's knowledge measures, and opportunities for future research and practice to enhance them.

Final Chapter to appear in the forthcoming:
*Managing Knowledge for Sustained Competitive Advantage:
Designing Strategies for Effective Human Resource Management*
Susan Jackson, Michael Hitt, & Angelo DeNisi, Editors.
San Francisco, CA: Jossey-Bass Publishers

Comments Welcome.

Strategic Knowledge Measurement and Management

Introduction

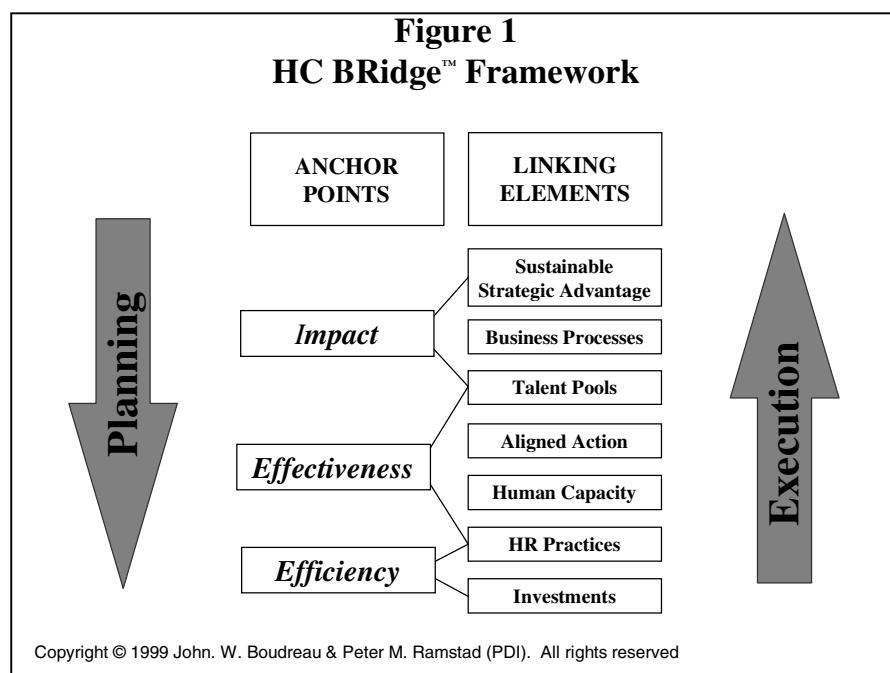
The strategic value of human capital, knowledge and talent is now well established. The other chapters in this volume attest to their essential roles in organizational value creation, uniqueness and competitiveness. This chapter focuses on measuring knowledge. Most research in industrial-organizational psychology (I-O) and even human resource management (HR) has focused on knowledge measurement at the level of the individual (e.g., competencies, skills, abilities, understanding, etc.), so this chapter will focus on knowledge measurement at more aggregate levels, and on the connection between knowledge measures and the competitive value proposition of organizations.

Knowledge is increasingly important to competitive advantage (DeNisi, Hitt & Jackson, this volume; Evans & Wurster, 1998, 1999; Rayport & Sviokla, 1995; Seely-Brown and Duguid, 2000), so information *about* knowledge – knowledge measurement – becomes even more critical. As Boudreau and Ramstad (in press) have noted, human capital measures, including knowledge measures, not only enhance decisions of HR leaders (Boudreau, 1991; 1996), they send signals to constituents such as financial analysts (Low & Seisfeld, 1998), prospective and actual employees (Cappelli, 2000) and shareholders. Measuring knowledge systematically supports better decisions about human capital, and signals how knowledge is valued.

Simply creating knowledge measures does not achieve these goals (Boudreau & Ramstad, in press). Researchers need to look beyond merely developing measures, and develop measures that connect talent to strategic success. Rich and articulated connections, supported by measurement, explain the effectiveness and prominence of decision systems such as Finance and Marketing (Boudreau & Ramstad, 1999; 1997). Thus, knowledge measurement should articulate, test and reinforce connections between knowledge and competitive advantage. DeNisi, et al. (this volume) similarly note that competitive advantage rests not on simply possessing resources, but in the way they are exploited by organizations.

There is no shortage of knowledge measures or consulting products (toolboxes, navigators, scorecards, dashboards, etc.) that propose to measure intellectual capital, knowledge or learning (e.g., Bontis, Dragonetti, Jacobsen & Roos, 1999; DiFrancesco & Berman, 2000; Sveiby, 1997; Roos & Von Krogh, 1996; Petrash, 1996; Economist, 1998; Low & Seisfeld, 1998; Stewart, 1998; Barsky & Marchant, 2000). A recent survey of senior executives in 158 companies found that 80% of companies had knowledge management (KM) efforts, 60% expected to use KM enterprise-wide within five years, 25% had a chief knowledge officer, and 21% had a KM strategy (Hackett, 2000).

Yet the definition of knowledge remains elusive (Crossan, Lane & White, 1999; Dodgson, 1993; Fisher & White, 2000), and there remains a “black box” of intervening variables that affect how knowledge can be enhanced, and how they contribute to organizational success (e.g., Argote, Ingram, Levine & Moreland, 2000, p. 4; Collins, 2000, p. 3). Boudreau and Ramstad (in press) adopted a new metaphor – a bridge of linking elements – to replace the “black box,” as shown in Figure 1. The details of this framework are covered elsewhere (Boudreau, Dunford & Ramstad, 2001; Boudreau & Ramstad, in press). The principles of the framework help to articulate the purposes of this chapter, and its conclusions.



Chapter Goals

The Editors of this volume suggested that this chapter explain how to design strategically appropriate measures to assess the role of knowledge in the organization's value chain. I-O psychology measures knowledge primarily at the individual and HR-program level. In terms of Figure 1, I-O and HR research has generally focused on elements of "Effectiveness," particularly individual differences (human capacity) and HR or I-O initiatives (HR practices), and their associated relationships (DeNisi, et al., this volume). Some studies relate knowledge-based HR practices directly to financial outcomes, but measuring knowledge at aggregated levels has not been a primary focus of I-O researchers. The linking elements of the "Impact" portion of the HC BRidge™ model (pools of talent, business processes and strategic success) have not been central to I-O research. As DeNisi et al. (this volume) point out, fruitful research and practical opportunities exist in understanding not only the traditionally-studied individual differences related to knowledge ("Human Capacity" in Figure 1), but the tasks and context that enables their contribution to competitive advantage ("Effectiveness" and "Impact" in Figure 1).

Measures that vividly reflect these linking elements exist in other disciplines including accounting, economics, psychology, political science, and operations management. So, this chapter will attempt to encourage a broadening of measurement in I-O and HR research by illustrating these measures. This becomes particularly necessary to reflect elements including not only knowledge capital, but also social capital and reputational capital (DeNisi, et al., this volume). Future researchers, managers and consultants may consider integrating the traditional focus of I-O – the individual and the intervention, and the traditional paradigms – cognitive psychology and organizational behavior, with emerging knowledge at more aggregate levels, and from a wider array of disciplines.

Aggregated Units of Analysis, Competitive Value-Chain Context, and "Pivotal Roles"

Three related themes are helpful to organize and develop research implications about knowledge measurement, from the examples described here. First, these measures focus on

aggregated units of analysis (that comprise groups of individuals), including profit centers, alliance partners, firms and even regions and economies.

Second, these measures strive to articulate the link between knowledge and the strategic value proposition of the organization, or the *value-chain context*. The term value chain refers to the system of “business processes” (see Figure 1) that support competitive and strategic success. For example, if one sets out to measure knowledge as embodied in organizational “learning curves” reflecting production efficiency, it is incumbent to identify key measures of production efficiency, and how they fit the particular value chain being examined. I-O research may find value in measures that more closely link knowledge outcomes to the value context of organizations.

Third, focusing on the value chain and the role of knowledge in it highlights the importance of talent pools in Figure 1, and particularly the idea of “*pivotal roles*” (Boudreau & Ramstad, in press). Pivotal roles are those where performance or quality differences between individuals have the greatest impact on organizational value and competitiveness. The measures described in this chapter are frequently constructed specifically to focus on organizational units, teams or jobs most likely to affect competitive advantage. For example, research on patent and patent citations has often identified areas of research and types of researchers likely to be particularly relevant to certain markets or production processes.

This chapter will describe two general roles for the measures discussed here, in I-O research: (1) As higher-level dependent variables which can help validate knowledge effects typically measured at the individual or intervention level of analysis; (2) As moderator or mediator variables, which help to explain why the effects of HR interventions on knowledge may vary with context, or that serve as intervening variables between HR interventions, individual differences and higher-level knowledge outcomes. The chapter explicitly excluded literature focusing primarily on general principles of individual learning, cognition, and traditional HR research on knowledge, skills and abilities, because other chapters in this volume focus on those issues.

A Framework for Knowledge Measurement

Fisher and White (2000, p. 245) noted, “The literature and research on organizational learning are so fragmented that there is no widely accepted model or theory.” The definition of knowledge is elusive (see also Walsh & Ungson, 1991, p. 57; Dodgson, 1993, p. 376). Crossan, et al. (1999, page 522) noted that despite over 30 years of attention to organizational learning, there is “little convergence or consensus on what is meant by the term.” Thus, we are limited by the lack of a universal approach to multidisciplinary knowledge measures. Still, this also creates opportunities. Precisely *because* they have not been widely integrated, these measures span a diverse set of theoretical and empirical perspectives.

Walsh and Ungson (1991) recognized that knowledge resides in organizational memory, manifested in “retention facilities,” including individuals, culture, transformations, structures and ecology. Dodgson (1993) and others have noted that research on knowledge can focus on outcomes of learning, the processes of learning, and the structures and strategies that enhance learning (p. 377). DeNisi, et al. (this volume) note that knowledge must include “what employees have mastered as well as their potential for adapting and acquiring new information.” Deeds (this volume) also employed the stock-flow concept, noting that it can be usefully combined with the tacitness of knowledge. Thus, this chapter will use a three-category organizing framework for knowledge measures: *Stock, Flow and Enabler*.

Stock, Flow and Enabler

Stock – *The existing level of knowledge at a point in time.* For example, Argote and Ingram (2000) suggest that knowledge is held in three basic “reservoirs” or elements of organizations – Members, Tools and Tasks, as well as their connections and networks. Fiol (this volume) noted the under-rated importance of *retiring* knowledge that has outlived its usefulness.

Flow – *Movement of knowledge between entities, including individuals, organizations or organization levels.* This includes notions of knowledge transfer, organizational learning, group interaction, and information flows through networks. Nahapiet and Goshal (1998) correctly

noted that the nature of knowledge transfer mechanisms, including social networks, must be considered part of an organization's knowledge resources. Connor and Prahalad (1996) suggested that knowledge acquisition, transfer and use are significant reasons for the existence of firms. Fiol (this volume) notes that knowledge flows should be conceived not only as "pipelines" that reflect traditional movement of disembodied knowledge, but also as "rivers" that reflect the myriad personal and social inflows and outflows of knowledge, and the unpredictability of its flow patterns. Though the "river" metaphor is much less common in research and practice, this chapter will describe measures of such social and personal processes, including elements of the "community" that nurtures knowledge.

Enablers – Investment, processes, structures and activities established by organizations aimed at changing or maintaining knowledge stocks, or influencing knowledge flows. Argote and Ingram (2000, p. 153) suggest that knowledge *about* the network (e.g., who knows whom, which members can use what tools, etc.) is likely to be important, and that collective knowledge can be measured through task sequences, software, and production processes. Knowledge can be differentially "tacit," or difficult to move. It is embodied in the existence of common meanings or interpretation systems (Walsh & Ungson, 1991; Kogut & Zander, 1992). Thus, knowledge can be measured through enabling mechanisms, which include organization design, alliances, network design, transactive memory, membership in cooperative initiatives, regional clustering, absorptive capacity, research and development, and HR practices.

Table 1
Knowledge Measures

Stocks	Flows	Enablers
<ul style="list-style-type: none"> • Accounting • Augmenting financial statements • Patents or publications and their citation patterns • Organization experience and competitive rivalry • Learning curves • Unit-Level Education, Experience and Job Requirements • “High-Performance” Work Systems 	<ul style="list-style-type: none"> • Performance changes between units or firms • Type of alliance reorganization • Perceived knowledge flows between units and alliance partners • Movement of routines, tools and ideas, including patents • Perceived information exchanged or awareness of knowledge available in other units • Collaboration and information sharing between colleagues • Analysis of work products for sources of ideas and information 	<ul style="list-style-type: none"> • Geographic and political proximity • International and Domestic Organizational and Alliance Design • R&D expenditures • Absorptive capacity • Network attributes (strength, intensity, structure, communication, individual movement) • Tacitness

Table 1 organizes the knowledge measures discussed here using these three categories. One way to use Table 1 as a research guide, is to consider that *Enablers* facilitate knowledge *Flows* which change knowledge *Stocks*. Perhaps even more interesting is to consider the measures in Table 1 as primarily oriented toward the “Impact” part of Figure 1, while the HR practices and individual differences that are the typical focus of I-O exist within the “Effectiveness” element of Figure 1. Thus, traditional I-O research might add the variables in Table 1, to enhance context and connections to outcomes. The next sections will illustrate the measures in Table 1, and suggest how they can serve as dependent variables, and moderator/mediator variables.

Measuring Knowledge Stocks

“Stock” measures provide a snapshot of the *level* of knowledge at a particular time. They reflect knowledge, but also organizational performance (e.g., survival or cost) and individual attributes (education and experience) as proxies for knowledge.

Accounting for Intangibles

It is fitting to begin with measures that emanate directly from the accounting statements, because such statements are often considered the ultimate measure of strategic success. Accounting-based knowledge measures strive to reconcile the difference between the *market value* of a firm’s shares in the financial markets with the *book value* of the assets recorded in financial statements. Lev and Zarowin (1999, p. 362) present data showing that “overall results indicate a weakening of the association between market values and accounting information (earnings, cash flows, and book values) over the past 20 years,” prompting proposals to augment financial statements with more information about “intangible” assets. This type of measurement has been called “financial statement reconciliation” (Boudreau and Ramstad, in press). The logic is that knowledge investments (e.g., the costs of a new organizational design, training programs, hiring of R&D employees, general R&D) are traditionally subtracted as accounting expenses, yet their benefits may accrue over time, so the accounting system fails to reflect their value as assets. This argument was first made in “human resource accounting” (Flamholtz, 1999).

Baruch Lev has coined the term “knowledge-based earnings.” As described in CFO Magazine (Mintz, 1999), knowledge based earnings are calculated by first forecasting corporate earnings for three future years. Then, the earnings due to traditional assets are estimated by assuming a level of expected return (e.g., 7 percent for tangible assets), and multiplying that percentage by the amount of traditional assets on the books. Subtracting the estimated earnings from traditional assets from the total forecasted earnings leaves a residual amount called “knowledge capital earnings.” To transform this earnings amount into the level of “knowledge assets,” one must assume a rate of return on knowledge assets (CFO Magazine

used 10.5 percent), and then divide estimated knowledge capital earnings by this percentage, to estimate the total knowledge-based assets. CFO Magazine publishes a compendium of company comparisons called the “Knowledge Capital Scorecard” each year (e.g., Osterland, 2001).

Financial Statement Augmentation

“Financial Statement Augmentation” (Boudreau & Ramstad, in press) describes measures that add human capital indicators to traditional financial information (e.g., Skandia corporation, 1996). Such reports include measures as diverse as total training expense, the number of employees under 30, and the number of patents (Barsky & Marchant, 2000; Batchelor, 1999; Dzinkowski, 1999, 2000; Flamholtz, 1999; Lewis & Lippitt, 1999; Lynn, 1998; Roslender, 2000; Sveiby, 1997). However, there is no standard format, so such reports may contain virtually anything an organization considers relevant or noteworthy. Skandia, includes over 100 measures in their “intellectual capital report” (Edvinsson and Malone, 1997), including replacement and acquisition costs, development of cross-functional teams, external relationships, information technology investments, and adoption of industry quality standards. Human resource accounting (Flamholtz, 1999) measures acquisition cost, replacement value, or the discounted value of expected future salaries.

Conclusions Regarding Accounting and Financial Statement Augmentation

Accounting focuses on reconciling the gap between traditional reporting the growing importance of knowledge and intangibles. The “residual” approach takes what can be accounted for traditionally and subtracts it from estimated total value to reveal “intangible” value. The “augmentation” approach adds to traditional accounting reports measures presumed to reflect knowledge.

In terms of *aggregated units*, accounting approaches often require the existence of standard financial statements, which presume an entity of sufficient size to have accounting records and transactions. In terms of *competitive and value-chain context*, the measures are rather generic. They usually do not describe the mechanisms through which organizations

create value, nor focus on how knowledge interacts with the value-creation processes. Rates of return are often estimated using averages within industries, and competitive processes are assumed to be reflected in the overall financial position. In terms of *pivotal roles*, these measures seldom identify which roles might most affect value through performance or quality differences. Though some financial statement augmentations attempt to report knowledge-based activities for key groups (e.g., training for research scientists, or the number of employees with qualifications in certain technologies), the links between roles and value are not explicitly identified.

For I-O researchers, accounting measures provide high-level dependent variables, such as the level of knowledge assets and returns from those assets. One can imagine studies asking, “Do knowledge-enhancing interventions or changes in individual knowledge levels relate to changes in the accounting levels or returns from knowledge assets?” Current HR strategy research often calculates relationships between HR practices and traditional financial ratios (see Boudreau & Ramstad, in press for a review). Perhaps financial results adjusted to reflect intangibles provide an even more appropriate dependent variable. Do knowledge-based interventions relate more strongly to accounting estimates of intangible assets than to traditional accounting outcomes?

I-O research and theory might contribute to financial statement augmentation by suggesting which human capital numbers should be used. Financial augmentation typically reports training expenditures, numbers of employees, and human resource activities meant to indicate investments in knowledge-based assets. Theories and findings from I-O research on knowledge might well identify the most appropriate expenditures or activities to report.

Accounting-based measures may provide fruitful moderating and mediating variables. Knowledge-enhancing I-O and HR interventions may be differentially effective depending on the rate of return to knowledge in the organization. Organizations with strong financial returns to knowledge may be more receptive to knowledge interventions, thus enhancing their effects. Similarly, the information reported in financial augmentation statements (e.g., number of training

programs, number of employees with advanced degrees, etc.) might be used to detect organizational receptivity to knowledge-based initiatives.

Patents, Publications and Citations

Disciplines as diverse as strategic alliances, network analysis, industrial-organizational economics and international relations have used patents to measure knowledge. Patented ideas represent the result of government scrutiny and endorsement of originality and usefulness. Patents are an outcome of knowledge, but it can also be argued that they represent part of the stock of knowledge, because they are protected ideas, which the firm has exclusive rights to use. Closely related to patents is the amount and pattern of research publications generated and used by an organization. Publications are not protected like patents, but they also reflect an external judgment (the scientific field) that ideas are original and useful. Publications and patents can be objectively traced to an organization. Moreover, patent and publication citations provide valuable insights regarding the sources and patterns of knowledge used, as we shall see.

There is surprisingly deep and informative information available about patents. Deng, Lev and Narin (1999) describe a data base of U.S. patents and citations that measures not only the number of patents, but their citation. Citations of scientific studies in patent applications indicated the "basic" knowledge embodied there. The number of patents, citation impact and science link were positively related to market-to-book value and stock returns. Sjöholm (1996) measured cross-border patent citations as knowledge flows between nations. Adams (1990) measured total knowledge in an industry as the number of scientific articles from that industry in each of nine scientific fields, weighted by the number of scientists allocated to each industry-field combination. Spencer (2000) examined archival data on articles published by researchers in Japanese and U.S. firms, measuring publication *Volume* (the number of articles), *Quality* (the number of times scientists in outside organizations cited the research), and *Breadth* (the number of different organizations whose scientists cited the work). Sorensen and Stuart (2000) used archival patent data to indicate innovation (citations to newer technology), and knowledge

close to the existing core (self-citations). Hall, Jaffe and Trajtenberg (2000) note problems of noise in patent data, and provide several methods for estimating patent quality. They found financial returns more highly correlated with citation-weighted patents than simple patent quantity.

Conclusions Regarding Patents and Publications

Patents, publications and citations reflect *aggregated units of analysis*, with a focus at the level of the firm or business unit. Rich archival data across firms and industries offers significant opportunities. Moreover, because patents, publications and citations are also associated with individuals, these measures offer I-O researchers measures that could potentially span units of analysis from individuals to business units and organizations. Several studies have found patent and citation-based measures to relate to financial outcomes, enhancing the strategic rationale for these measures. In terms of *value-chain context*, patents and publications can be classified by particular fields and groups of knowledge-worker (e.g., R&D scientists), and thus can be explicitly linked to different areas of the value chain, and to different competitive processes. For example, Jaffe (1986) explicitly linked patent citations to particular competitive processes in R&D. Patents are also quite useful in identifying and describing *pivotal roles*. They reflect the fields of expertise of individuals, and citation records can trace which knowledge roles have had the most significant impact on the knowledge base, and in which business processes.

Thus I-O research could use of patents and publications as dependent variables, examining whether they are affected by knowledge-enhancing interventions, offering externally-verified evidence of the effect of individual or program-level knowledge changes. Because patents, publications and citations can be also be so specifically linked to the value-chain, they offer useful intervening variables that may help to explain the links between knowledge changes at the individuals or program level, and eventual organizational returns. Finally, levels and patterns of patents and publications might provide useful moderator variables to explain contextual differences. For example, firms with a large number of highly-cited and value-

relevant patents might benefit more from knowledge-enhancing interventions, or from enhancements in individual knowledge, because the “platform” for using such knowledge is already very high.

Organization Experience and Rivalry Patterns

Measures of “organization experience,” reflect the time and volume of production or services offered. The idea is that as organizations operate, they gain knowledge. DeNisi, et al. (this volume) note that such knowledge can come from competitors and customers, as well as from access to experienced employees. Data reflecting organization experience are often available through archival directories. For example, Baum and Ingram (1998) used the Manhattan Classified Director/Yellow Pages, the Annual Directory of the Hotel Association of New York City, and the Hotel and Travel Index, to track “life history” information on 558 hotels operating in New York from 1898 to 1980. Industry experience was the number of rooms offered over time. Hotel “experience” was found to matter early in the life cycle, through learning from similar hotels. Organization experience is also measured by exposure to competition. Ingram and Baum (1997) constructed measures of competitive experience for hotel chains, including geographic dispersion of units and industry competitive intensity as the number of hotel failures over time. Barnett, Greve and Park (1994) applied this method using *The Bankers Directory*, which codes the existence and assets of banks, their place of operation and events such as foundings, dissolutions and mergers. They measured bank experience in terms of density of rivals and branches. Barnett and Hansen (1996) found banks failed more often if they had more exposure to varied rivals early in their history. In an international context, Barkema, Shenkar, Vermeulen and Bell (1997) gathered data on the number of domestic joint ventures and international subsidiaries at the time of entry into a new country.

Learning Curves

Learning curves provide a particular interpretation of production experience, reflecting the reduction in unit costs and tangible process improvements that come with experience in specific production processes. Arrow (1962) first suggested that the “very activity of production

gives rise to problems for which favorable responses are selected over time" (p. 156). Epple, Argote and Devadas (1991) provide helpful definitions and derivations of learning curve indices, and Darr, Argote and Epple (1995) provide vivid descriptions of the social processes of learning curves, such as how an innovation in placing pepperoni on pizzas was learned by other pizza stores. Learning curves are estimated using archival production data from business units (e.g., pizza stores, production plants, production shifts). Darr, et al. (1995) and Darr and Kurtzberg (2000) obtained data on pizza's sold and production costs from regional offices of pizza franchise corporations. Epple, et al. (1991) and Epple, Argote and Murphy (1996) gathered data from two work shifts in one truck production plant. Hoopes and Postrel (1999) measured reduced "glitches," or preventable process problems caused by a lack of coordination.

Conclusions Regarding Organization Experience, Rivalry and Learning Curve Measures

In terms of *aggregated units of analysis*, organizational experience and rivalry can clearly be measured at the level of the firm, and perhaps even more usefully at the level of the business unit, division, production process or work shift. Detailed directories in many industries provide excellent archival sources that might be used to verify individual perceptions of rivalry or experience. One can even imagine measuring individual differences, such as whether employees have worked in business units or industries with more or less rivalry and competition. This might usefully enhance more typical measures of organizational tenure or number of jobs held. In terms of the *value-chain context*, rivalry and competition measures are less specific, because they reflect the number and age of business units, rather than elements of the value chain. However, learning curve measures address this shortcoming, focusing on specific key manufacturing or other processes, and process quality. Similarly measures of industry experience and rivalry do not reflect *pivotal roles*, because of their focus on business units, and learning curves *per se* provide little information about particular roles. However, learning curve research often gathers qualitative data suggesting how particular employees actually learned or implemented process improvements (e.g., how pizza store employees

shared their knowledge about pepperoni placement), potentially allowing researchers to determine which roles are most key in knowledge transfer.

Thus, in I-O research, organizational experience measures, as well as learning curve measures, offer additional dependent variables. For example, one effect of changes or differences in knowledge among individuals or HR programs might be changes in the survival and/or successful entry into more competitive environments. Research questions might include, “Do firms or business units with knowledge-enhancing HR practices tend to have more industry experience? Does enhanced knowledge among individual employees or the existence of knowledge-enhancing HR practices relate to accelerated learning-curve progress?” Industry experience and learning curves also have potentially significant value as moderators and mediators in I-O and HR research. For example, individual knowledge and knowledge sharing regarding successful competitive practices might be more valued and more related to financial performance among firms facing highly competitive environments, because competition makes innovation more valuable. The relationship might even be non-linear (a ceiling effect) if highly competitive environments present such significant day-to-day challenges, particularly for firms with little experience, that HR practices and individual knowledge changes are simply not used or transferred. Businesses or units that are “early” in the learning curve might benefit more from interventions designed to enhance individual ability to receive knowledge, while those further into the learning curve process might benefit most from interventions that enhance knowledge sharing.

Unit-Level Competencies, Education and Experience

Clearly, this category encompasses a wide variety of attributes such as cognitive ability, training results, performance ratings, and competencies (Lado & Wilson, 1994). The measurement of competencies is a field in itself, with a vast array of products and technologies that generally focus on the individual level. Many of them are covered in other chapters of this volume.

This section focuses on measures of these attributes at the level of jobs, production processes, firms and industries. Much of this research emanates from labor economics, with roots in the concepts of human capital (e.g., Becker, 1964). For example, Leigh and Gifford (1999) used the National Longitudinal Survey of Youth (NLSY), which asked workers about amount and type of their training and who paid for it. Coff (1999) calculated the knowledge intensity of industries using reported education and training required for jobs. Cappelli (1993) used data from Hay Associates, on job attributes including “Know-How”, “Problem Solving” and “Accountability.” Tomlinson’s (1999) survey asked, “Whether the person’s job required that they ‘kept on learning new things’” (p. 437). Cappelli’s (1996) survey asked, “Have the skills required to perform production jobs adequately risen over the last three years?” Cappelli (1993, 1996) suggests that the skill-level of industries and organizations can be assessed in several ways, including Dictionary of Occupational Titles job analyses, “production functions” (the level or type of capital spending), and “work organization” indicated by the presence of high-performance HR practices.

Conclusions Regarding Unit-Level Education, Experience and Job Requirements

Aggregated units of analysis are probably the most distinguishing feature of these measures. They emanate from the presumption that certain work demands, job requirements or occupational titles (e.g., engineer) indicates the presence of individual-level knowledge, allowing unit-level experience and education to be measured directly rather than aggregating individual-level attributes. I-O researchers might use such measures when individual-level data is unavailable, difficult to obtain, or unreliable. These measures do not specifically incorporate the *value-chain context* or *pivotal roles*, but they often choose to focus on particular jobs or work areas, suggesting which areas are critical to organizational value creation.

As additions to I-O research designs, these variables might offer alternative dependent variables. For example, in addition to tracking the immediate effects of HR interventions on individuals, researchers might also measure whether managers perceive that work requirements have changed, or whether the jobs involved begin to attract more knowledge

workers (e.g., engineers or scientists). They also may provide useful moderator or mediator variables, to explain contextual variance. For example, business units that exhibit rising knowledge demands using these measures might be more likely to exhibit strong effects of knowledge-enhancement interventions, because their work environment is becoming more demanding.

Measuring Knowledge Flows

A distinguishing feature of organizational learning (as opposed to individual learning) is that it occurs through transfer of routines, culture, and processes, through collective interpretation (Cohen, 1991). Crossen, et al. (1999) define organizational learning as movement of knowledge through and between individual, group and organizational units. DeNisi, et al. (this volume) noted that continuous organizational learning may be particularly difficult for competitors to duplicate. Knowledge flows can be measured by tracking changes in the measures of knowledge stocks described in the last section. Patent citations, for example, reflect the quality of knowledge, but also indicate who has used prior developed knowledge (Hall, et al., 2000; Mowery, Oxley & Silverman, 1996; Almeida, 1996, Spencer, 2000). Or, relative changes in learning curves can indicate knowledge movement (e.g., Baum & Ingram, 1998). Argote and Ingram (2000) defined knowledge transfer as “the process through which one unit (e.g., group, department, or division) is affected by the experience of another” (p. 151).

I-O and HR research typically defines knowledge transfer as applying knowledge from one setting (e.g., the classroom) to another (e.g., actual work behaviors). This same principle has been fruitfully applied to knowledge movement between organizations, business units, groups and teams, as this section will illustrate. One group of measures focuses on business units and alliance partners, and another focuses on groups and teams.

Knowledge Flows Between Units and Alliance Partners

Business alliances are often formed to obtain knowledge (DeNisi, et al., this volume). Deeds (this volume) noted that “the ability of a firm to develop and manage cross boundary individual and firm relationships and learn from its prior experiences will be important to the

firms' competitive position," and is likely to increase. For example, in the pharmaceutical/biotechnology industry, Rothermael and Deeds (2001) documented over twenty two hundred active alliances. Deeds also noted that alliances are only one form of "hybrid organization" that range "from simple licensing agreements to complex alliances in which multiple parties are cross-licensing technologies and contributing to joint R&D to multiparty joint ventures in which a jointly owned organization is setup to pursue a new market or technology." He noted that evidence suggests a positive effect of alliances on R&D performance and organizational productivity, as well as the tendency for alliances to have difficulty in their "adolescence," similar to marriages. This section will thus illustrate measures of knowledge and knowledge transfer that focus on organizational units, particularly international and alliance partners.

Downes and Thomas (2000) used the number of expatriates as a proxy for national-market-specific knowledge and knowledge about international management. Shenkar and Li (1999) surveyed managing directors of Shanghai enterprises about three types of knowledge sought and offered to the potential partners: Management skills, marketing skills and/or technological know-how. Zahra, Ireland and Hitt (2000) measured technological learning in international joint ventures by surveying managers about the *breadth* (e.g., learned many different vs. a few skills), *depth* (e.g., how well your company has learned or mastered new skills) and *speed* (e.g., how fast your company learned). Simonin (1999) had experts rate agreement with attributes describing prior alliances, such as "technology/process know-how easily transferable" (p. 606). Gupta and Govindarajan (2000) surveyed subsidiary presidents regarding whether seven specific knowledge types were received or supplied by the subsidiary, the parent corporation or other subsidiaries: (1) marketing know-how; (2) distribution know-how; (3) packaging design/technology, (4) product designs, (5) process designs, (6) purchasing know-how; (7) management systems and practices.

A paradox of knowledge flows is, that while they can enhance learning *within* organizations, movable knowledge is also more easily appropriated by outsiders. This has been called "spillover" (e.g., Van Meijl & van Tongeren, 1999, p. 31). The effects of spillover are quite

different from useful internal knowledge transfer, but the measures are quite similar, the difference being that spillover focuses on undesirable movement between *competing* organizations. Jaffe, et al. (2001) measured spillover by the citation of research and patents produced in competing organizations. Almeida and Kogut (1999) measured spillover as the movement of major patent holders. Lane and Lubatkin (1998, p. 468) asked competitive intelligence analysts to consider particular industry alliances, and to estimate “which partner benefited most from knowledge spillovers.” Knowledge flows have also been measured using data from archival secondary sources. Dussauge, Garrette and Mitchell (2000) measured whether alliances were reorganized, taken over by one party, continued without change, or dissolved, defining the first two as representing “greater capability acquisition” (p. 104). Deeds and DeNisi, et al., (this volume) notes that premature turnover among key top managers or technical knowledge holders in an acquired company may indicate a loss of knowledge transfer.

Knowledge Flows Between Individuals and Groups

Measures of knowledge flows between individuals reflect the concept of knowledge “communities,” and that knowledge work “is about social connections and interpretations” (Fiol, this volume). Some knowledge flow measures have focused on the degree to which individuals disclose information. Appleyard (1996) asked respondents whether they provided information to colleagues. Lawson and Lorenz (1999) observed collaboration between University professors and company scientists. Bouty (2000) conducted interviews with 38 researchers working in France, measuring information exchanges with other scientists. McEvily, B., and Zaheer, A. (1999) surveyed top managers regarding their participation in assistance or user groups and whether they sought advice from individuals outside the firm. Inkpen and Dinur (1998) qualitatively evaluated how explicit was the knowledge shared between American and Japanese auto parts joint ventures.

“Shared reality”– convergence in group members’ judgments of ambiguous stimuli (Sherif, 1936) can also indicate knowledge transfer. Levine, Higgins and Choi (2000) noted that it can be embodied in beliefs, team mental models (Cannon-Bowers, Salas & Converse, 1993),

collective mind (Weick & Roberts, 1993) and transactive memory (Moreland, Argote, & Krishnan, 1996). Most measures focusing on this concept arose from experimental studies of groups. Moreland and Myaskovsky (2000) surveyed experimental subjects who constructed radios, asking, “How much do you think the other members of this group know about your radio-building skills?” “how similar are the skills in this work group?” and “how much do you know about the skills of others in this group?”. Levine, Higgins and Choi (2000) measured the convergence recollections of whether certain nonsense words had appeared in a list. Stasser, Vaughan and Stewart (2000) observed whether subjects mentioned information that had been shared with everyone or given only to one person in the group. Paulus and Yang (2000) measured the frequency of repeated ideas after a brainstorming session. Gruenfeld, Martorana and Fan (2000) counted ideas contained in individual and group essays, to examine how “outsiders” affect idea generation.

In the field, Bouty (2000) interviewed French researchers, coding anecdotes to reveal shallow exchanges (discussing published papers, products, general scientific information and giving names and addresses) versus deeper exchanges (sharing scientific and technical information, giving contacts and recommendations, sharing ideas about works in progress, giving product samples, and pre-reviewing papers). Fiol (this volume) describes a Paris-based advertising company that has employees rate the quality of information on their internal corporate web site, moving highly rated information to positions with top billing.

Conclusion Regarding Knowledge Flow Measures

The knowledge flow measures illustrated here focus on *aggregated units of analysis* that are either on business units and alliance partners, or groups and teams. Measures focused on business units rely primarily on surveys of unit leaders regarding perceived information flows, with a few attempts to use archival data. Measures focusing on groups and teams also rely on surveys, but more often actually measure how shared knowledge appears in work products and team results. Though such measures are usually applied in experimental settings, their similarity to the patent citation information discussed earlier is quite striking. Both measure the

use of knowledge from different sources in work products. Experimental studies provide very deep insights into the precise nature of individuals and situations that lead to knowledge use, while unit-level studies often provide access to objective archival data (e.g., actual citations), as well as identifying work groups according to their likely impact on organizational value. This point brings us to the issues of *value-chain context* and *pivotal roles*. Many of the unit-level flow measures relate very specifically to particular value-enhancing alliances, and even provide specific competitive scenarios which respondents are asked to consider. They generally focus on particular talent pools (e.g., R&D scientists) or frame their questions around particular business processes or goals (e.g., forming an alliance or inventing a new product or service).

Unit-level knowledge flow measures may provide higher-level outcomes to validate and calibrate I-O research results. It is interesting to consider the implications of applying both the experimental methods and the archival or business-unit survey methods in one study. The experimental methods would enhance understanding of group-level interactions, and their results might be compared with perceived unit communication, actual citation of work in publications or patents, etc. For example, information is likely to be differentially known to different groups in the field, suggesting the possibility of tracking whether that information is used in final products or reports, just as experimental studies have done. These measures also provide potential moderator or mediator variables. For example, I-O and HR interventions to enhance knowledge sharing may be more effective where unit-level measures reveal positive managerial perceptions of the conditions for knowledge flows between alliances, because the environment for sharing is more supportive.

Measuring Knowledge Enablers

Enablers facilitate changes in knowledge stocks or flows. The fact that enablers are present does not necessarily mean that they are actually used, and that knowledge is generated or moved. Still, enablers are included here because virtually every theory or concept of knowledge notes enabling mechanisms as essential. For example: DeNisi, et al. (this volume) note Pfeffer and Sutton's (2001) admonishment that, a key role of leadership is "to help build

systems of practice that produce a more reliable transformation of knowledge into action” (p. 261). Fiol (this volume) differentiates “enablers” (formal technologies and structures) from “drivers” (informal and social trusting communities). Here, the term “enabler” will encompass both ideas. Thus, enablers illustrate unique measurement opportunities, and a fertile set of candidates as moderator or mediator variables for I-O psychology researchers.

Geographical and Political Proximity

Several authors have measured physical, personal or political proximity as knowledge enablers. Maskell and Malmberg (1999) assert that smaller firms benefit from close geographic proximity by sharing knowledge and other resources. Torstensson’s (1999) measure of membership in cooperative institutions (such as the European Union) predicted country growth. Capello’s (1999) survey measured “location advantages” (e.g., proximity to airports, and cultural or industrial centers). Zahra, et al. (2000), measured “international diversity” using secondary sources and surveys of managers on the number of countries generating products or revenues.

International and Domestic Organizational and Alliance Design

Measures focusing on international organizational design include the number of domestic and international joint ventures (Barkema, Shenkar, Vermuelen & Bell, 1997). Dyer and Nobeoka (2000) used archival and survey data to map a particularly comprehensive set of interactions among Toyota’s supplier network, including subsidies to the network, meetings and committees, problem-solving teams combining Toyota and supplier employees, employee transfers to suppliers, free information access, open access to supplier plants, and perceived benefits of sharing knowledge. Finally, Hitt, Dacin, Levitas, Arregle and Borza (2000) used a policy-capturing survey of executives in 202 firms, presenting 30 hypothetical case studies that varied 14 potential alliance partner criteria, including "complementary capabilities," "unique competencies", "market knowledge/access" "intangible assets", "managerial capabilities", and "willingness to share expertise.”

Some measures exploit archival information on financial and reporting structures. Darr

and Kurtsberg (2000) measured pizza stores in terms of strategy, customers and geography. Barnett, Greve and Park (1994) divided banks into branch-bank and “unit” structures. Powell, Koput and Smith-Doerr (1996) used the BIOSCAN database to measure the extent and centrality of formal agreements between different biotechnology firms and various partners.

Fiol (this volume) noted that organization structures can be measured in terms of their complexity, number of levels, and their level of specificity. Fiol also notes that organizational structures may be subordinate to social processes, in explaining knowledge flows.

Research and Development (R&D) Expenditures

Archival records of R&D spending provide an economic indicator knowledge required in jobs, industries or countries (e.g., Berman, et al., 1994; Bhagat & Welch, 1995; Lane & Lubatkin, 1998; Torstensson, 1999; Zahra, et al., 2000). Helfat (1997) used a rich measure of R&D expenditures from the U.S. Department of Energy database, including total R&D for the 26 largest U.S. energy firms, and the breakdown of R&D expenditures by type of business.

Absorptive Capacity

The capacity to absorb new knowledge can be associated with organizations, units and partners (Cohen & Levinthal, 1990). Absorptive capacity measures overlap with some of the knowledge “stock” measures noted earlier, because having prior knowledge aids assimilation and exploitation of new knowledge (e.g., Cohen and Levinthal, 1989, regarding R&D). Deeds (this volume) noted that absorptive capacity, and the proximity between the knowledge bases of two alliance partners, may determine which sort of alliance arrangements (e.g., licenses, mergers, etc.) will be most effective.

Helfat (1997) measured a firm’s “absorptive capacity” for coal gasification in terms of the level of complementary R&D already being done. Van den Bosch, Volberda and DeBoer (1999) described publishing firms moving into multi-media, defining absorptive capacity in terms of prior related knowledge as well as the organizational form (function, division and matrix) and combinative capabilities (systems, coordination, socialization). Lane and Lubatkin (1998) measured of the absorptive capacity of pharmaceutical companies forming alliances with

biotechnology start-ups using archival data on publication patterns. They calculated the overlap in the research communities where publications by alliance partners appeared. Measures included the total overlap of publication communities; overlap in “basic” knowledge (biochemistry); overlap in “specialized” knowledge (neurology, endocrinology, etc.); percentage of research communities in a scientific discipline in which the partner is active. They also measured organizational “knowledge processing similarity” such as formalization and centralization, incentive pay, and emphasis on scientific publications in the firm.

The Network¹

Attributes of individual and organizational networks are clearly a key enabler of knowledge flows. Wasserman and Faust (1994), provide an excellent treatment of many of the major approaches, including methods based on graph theory and matrix analysis, etc. For example, “strong” versus “weak” ties (Granovetter, 1973) can be measured through affective reactions about relationships between individuals or groups (Hansen, 1999, p. 94). “Structural holes” describe network points that fill unique gaps (Burt, 1995).

Kogut (2000) applied these concepts to the interaction patterns among Toyota suppliers. Collins (2000) measured network size, range and strength of ties by asking top managers to list contacts from nine external categories (e.g., suppliers, customers, financial institutions, etc.) and four internal categories (e.g., sales, R&D, etc.), and then to rate the relationships on dimensions such as frequency, duration and intensity. Appleyard (1996) surveyed the importance of nine sources of technical information: (1) Colleagues in your company; (2) technologists at other companies; (3) equipment vendors; (4) materials suppliers; (5) customers; (6) benchmarking studies; (7) presentations at conferences; (8) journals, books, etc.; and (9) patents. Subrahnam and Venkatraman (2001) surveyed senior managers about the frequency of their telephone, fax and e-mail exchanges to and from overseas managers. Hage and Hollingsworth (2000) noted that there are “numerous sets of data from which one may obtain

1 Ben Dunford made particularly helpful contributions to this section.

measures of the connectedness/communication among actors, such as the European Commission's (1997) Community Information Survey and from the National Science Foundation in the U.S." (p. 986).

Networks can be traced through movement of individuals. Almeida and Kogut (1999) examined the actual movement of patent holder, and Capello (1999) interviewed Italian managers regarding the previous employment and training of technicians, and their turnover.

Fiol (this volume) notes the importance of trust in enabling knowledge. Glaeser, Laibson, Scheinkman and Soutter (2000) found that attitude surveys predicted trustworthy behavior much better than trusting behavior. The World Values Survey contains a set of items tapping trust at an economic institutional level, which has been applied in over 20 countries (e.g., Knack & Keefer, 1997).

Tacitness

"We know more than we can tell" (Polyani, 1966, p. 4). Knowledge "tacitness" reflects the effort required to move it (Almeida & Kogut, 1999). Tacitness is an enabler because it affects the ease of knowledge transfer, and the effectiveness of other enablers (e.g., DeNisi, et al., this volume; Lam, 2000; Lawson & Lorenz, 1999). Tacitness can be harmful when it restricts desired knowledge flow between groups, but also valuable in making knowledge difficult for competitors to copy (Teece, Pisano, & Shuen, 1997; Barney, 1991). Definitions of tacitness abound. Several authors (Gupta & Govindarajan, 2000; Helfat, 1997; Kogut and Zander, 1992) distinguish "know-how" (procedures) as distinct from "know-what" (facts). Spender (1996) defined three types of tacit knowledge: *Conscious* is codified at the individual level (notes), *Automatic* is completely implicit, and *Collective* is held by the community or group.

Zander and Kogut (1995) surveyed engineers about specific innovations in their firm, obtaining ratings of codifiability (embedded in manuals, software and documents), teachability (easily learned or taught), complexity (changing physical characteristics, shape, dimensions and assembly), and system dependence (impossible for one person to know everything, requires frequent interpersonal contact). Simonin (1999) surveyed managers regarding the degree to

which alliance partner technology was “easily codifiable in written instructions” and “know-how more explicit than tacit.” Tan and Libby (1997) defined tacit managerial knowledge as “knowledge of traits and behaviors related to managing self, others and career” (p. 105). They asked accounting firm partners and their employees to react to a set of scenarios, with tacitness indicated by larger deviations between employees’ and partners’ ratings. Subramaniam and Venkatraman (2001) had respondents rate information from overseas partners in terms of simple vs. complex, easy vs. difficult to document, communicate and understand from written reports, obvious vs. subtle to competitors, and easy vs. hard to identify without personal experience.

Conclusions Regarding Measures of Knowledge Enablers

In terms of *aggregated units of analysis*, enabler measures span the widest domain, ranging from very specific (the communication of specific items of information by individuals or the use or citation of particular ideas in work products) to more general (geographic proximity or organization design). The *value chain context* is well developed in these enabler measures, as they frequently reflect deep understanding of company strategies, and archival and financial data that illuminates key competitive aspects or results. For example, R&D expenditures and absorptive capacity measures are often constructed to focus on particular competitive innovations or value-chain elements. The relevance of existing knowledge for assimilating new knowledge is certainly recognized in I-O theories of individual knowledge transfer, and the measures describe here illustrate practical ways to apply the concept to organizations and business units, incorporating the value-chain. *Pivotal roles* are also evident in the measurement of network attributes, such as identifying individuals who fill “structural holes.” For example, Fischer and White (2000) noted that the turnover of such individuals may have negative implications for networks that go well beyond the individual’s job performance. This may offer one mechanism through which the loss of individuals can significantly affect a firm’s intangible resources and competitive advantage (DeNisi, et al., this volume).

The enabler measures noted here present research opportunities for I-O researchers. Perhaps their most obvious role would be as moderators or mediators in traditional I-O research. The nature of organizational design and alliances, the tacitness of knowledge, and the degree to which current knowledge provides a framework for absorbing new competitive knowledge would all seem likely to influence the effects of HR and I-O knowledge interventions. Moreover, because many of the measures are based on archival information, this provides an opportunity to tap additional constructs relatively unobtrusively. Even the survey measures described here could be incorporated into many I-O studies. The concept of “tacitness” seems particularly relevant to I-O research on knowledge transfer.

Some of these enablers may also provide useful high-level dependent variables. For example, R&D expenditures might be expected to rise in areas where firms are targeting investments in employee knowledge. If this is not happening, it might signal missed opportunities to capitalize on such investments. Where HR interventions are aimed at increasing knowledge communication and clarity, we might expect to see increases in measures of absorptive capacity and decreases in measures of tacitness.

Summary and Conclusions

This chapter distinguished measures according to *stocks*, *flows*, and *enablers*. These distinctions may prove useful to future researchers. Enablers and flows comprise measures that are likely intervening or moderating factors, and may help researchers understand or explain additional cross-context variation in the effects of HR and I-O variables on organizational outcomes. Knowledge stocks may prove useful as high-level dependent variables, as well as important moderators or mediators, particularly when the outcome variables reflect overall organizational financial results.

These distinction between stock, flow and enabler may also prove useful in identifying which measures in Table 1 are most likely to be affected by the HR practices, I-O interventions and individual differences that are the focus of the other chapters in this volume. Some HR practices or individual differences may be linked more closely to some categories than others. For example, training in group processes should probably manifest itself in an increased flow of knowledge, though it may or may not increase the stock of knowledge. On the other hand, incentives for creativity might be most likely to affect knowledge stocks (e.g., patents and cited papers), rather than flows or enablers.

Earlier sections noted that traditional HR and I-O research focuses at the HR program and individual level (*Effectiveness* in Figure 1) and could be extended to encompass the logic of business processes and competitive context (*Impact* in Figure 1). Also, the research that produced the measures describe here could benefit from understanding the HR and I-O practices and individual differences that affect the phenomena they measure. Most I-O readers have already recognized potential improvements in psychometric properties (e.g., single-item measures, perceptions of only single subjects, etc.) I-O principles of units of analysis might also suggest improvements such as validating the assumption that the existence of certain jobs (“scientist” or “expatriate”) indicates associated knowledge (“scientific principles” or “global awareness”).

Most of the research using higher-level knowledge measures makes an implicit assumption that organizations can create the teams or other design elements, with little discussion about how to do it. There is fruitful potential in explicating and testing these assumptions. For example, research on networks has suggested that certain personality types might be associated with those filling “structural holes” (Burt, Janotta & Mahoney, 1998).

Such integration will require I-O and HR researchers increasingly to understand and more explicitly measure industry and competitive context. This does not mean simply adding financial outcomes to traditional variables (e.g., HR practices or skill levels), but rather articulating the logical links between knowledge and *Pivotal roles*, *Value-chain* processes, and *Aggregated outcomes*. The measures described show this is possible. R&D expenditures have been specifically weighted for their relevance to particular manufacturing processes. Shared ideas are not merely counted, but are logically related to changes in production costs over time (“learning curves”). The field of knowledge management provides ample evidence that such a bridge is possible. Table 1 illustrates some of the rich and varied measurements to realize the potential.

References

- Abrahamson, E. (1991). Managerial fads and fashion: The diffusion and rejection of innovations. Academy of Management Review, 16, 586-612.
- Abrahamson, E. (1996). Management fashion. Academy of Management Review, 21 (1), 254-285.
- Adams, J. D. (1990). Fundamental stocks of knowledge and productivity growth. Journal of Political Economy, 98 (4), 673-702.
- Almeida, P. (1996). Knowledge sourcing by foreign multinationals: Patent citation analysis in the US semi-conductor industry. Strategic Management Journal, 17, 155-165.
- Almeida, P., & Kogut, B. (1999). Localization of knowledge and the mobility of engineers in regional networks. Management Science, 45 (7), 905-917.
- Appleyard, M. (1996). How does knowledge flow? Interfirm patterns in the semiconductor industry. Strategic Management Journal, 17, 137-154.
- Argote, L., & Ingram, P. (2000). Knowledge transfer: A basis for competitive advantage in firms. Organizational Behavior and Human Decision Processes, 82 (1), 150-169.
- Argote, L., Ingram, P., Levine, J. M., & Moreland, R. L. (2000). Knowledge transfer in organizations: Learning from the experience of others. Organizational Behavior and Human Decision Processes, 82 (1), 1-8.
- Arrow, K. J. (1962). The economic implications of learning by doing. The Review of Economic Studies, 29 (3), 155-173.
- Barney, J.B. (1991). Firm resources and sustained competitive advantage. Journal of Management, 17, 99-120.
- Barkema, H. G., Shenkar, O., Vermeulen, F., Bell, J. H. (1997). Working abroad, working with others: How firms learn to operate international joint ventures. Academy of Management Journal, 40, 426-442.
- Barnett, W. P. & Hansen, M. T. (1996). The red queen in organizational evolution. Strategic Management Journal, 17, 139-158.
- Barnett, W. P., Greve, H. R., & Park, D. P. (1994). An evolutionary model of organizational performance. Strategic Management Journal, 15 (Summer), 11-28.
- Barsky, N. P. & Marchant, G. (2000). The most valuable resource—measuring and managing intellectual capital. Strategic Finance, 81, 58-62.
- Batchelor, A. (1999, February). Is the balance sheet outdated? Accountancy, 123, 81.
- Baum, J. & Ingram, P. (1998). Population-level learning in the Manhattan hotel industry, 1898-1980. Management Science, 44, 996-1016.
- Becker, G. S. (1964). Human capital; a theoretical and empirical analysis, with special reference to education. New York: Columbia University Press.
- Berman, E., Bound, J., & Griliches, Z. (1994). Changes in the demand for skilled labor within US manufacturing: Evidence from the annual survey of manufacturers. The Quarterly Journal of Economics, 109, 367-397.
- Bhagat, S., & Welch, I. (1995). Corporate research and development investment: International comparisons. Journal of Accounting and Economics, 19, 443-470.
- Bontis, N., Dragonetti, N. C., Jacobsen, K., & Roos, G. (1999). The knowledge toolbox: A review of the tools available to measure and manage intangible resources. European Management Journal, 17 (4), 391-403.
- Boudreau, J. W. (1991). Utility analysis for decisions in human resource management. In M. D. Dunnette & L. M. Hough (Eds.) Handbook of Industrial and Organizational Psychology, (2nd ed.), Vol. 2. Palo Alto: Consulting Psychologists Press, pp. 621-745.
- Boudreau, J.W. (1996 b). "The Motivational Impact of Utility Analysis and HR Measurement." Journal of Human Resource Costing and Accounting, 1, 2, pp. 73-84.
- Boudreau, J. W., Dunford, B. B., & Ramstad, P. (2001). The human capital "impact" on e-business: The case of encyclopedia Britannica. In N. Pal and J. M. Ray (Eds.). Pushing the Digital Frontier: Insights into the Changing Landscape of e-Business. New York: AMACOM.

Boudreau, J. W., & Ramstad, P. M. (1997). Measuring intellectual capital: Learning from financial history. Human Resource Management, *36* (3), 343-356.

Boudreau, J.W. & Ramstad, P.R. (1999). Human resource metrics: Can measures be strategic? In P. Wright, L. Dyer, J. Boudreau & G. Milkovich (eds.) Strategic human resources management in the twenty-first century. Supplement 4 to G.R. Ferris (ed.) Research in personnel and human resource management, 75-98. Stamford, CT: JAI Press.

Boudreau, J. W. & Ramstad, P. M. (in press). Strategic I/O psychology and the role of utility analysis models. In W. Borman, R. Klimoski & D. Ilgen (eds.). Handbook of Industrial and Organizational Psychology.

Bouty, I. (2000). Interpersonal and interaction influences on informal resource exchanges between R&D researchers across organizational boundaries. Academy of Management Journal, *43* (1), 50-65.

Burt, R.S. (1995). Structural holes: the social structure of competition. Boston: Harvard University Press.

Cannon-Bowers, J.A., Salas, E. & Converse, S.A. (1993). Shared mental models in expert team decision making. In J.J. Castellan, Jr. (Ed.). Individual and group decision making: Current issues (pp. 221-246). Hillsdale, NJ: LEA.

Capello, R. (1999). Spatial transfer of knowledge in high technology milieu: Learning versus collective learning processes. Regional Studies, *33* (4), 353-365.

Cappelli, P. (1993). Are skill requirements rising? Evidence from production and clerical jobs. Industrial and Labor Relations Review, *46* (3), 515-521.

Cappelli, P. (1996). Technology and skill requirements: Implications for establishment wage structures. New England Economic Review, 139-155 May/June.

Cappelli, P. (2000). A market-driven approach to retaining talent. Harvard Business Review, *78*, 103-111. January/February

Coff, R. (1999). How buyers cope with uncertainty when acquiring firms in knowledge-intensive industries: Caveat emptor Organization Science, *10* (2), 144-162.

Cohen, M. D. (1991). Individual learning and organizational routine. Organization Science, *2* (1), 135-139.

Cohen, W. & Levinthal, D. (1989). Innovation and learning: The two faces of R&D. The Economic Journal, *99*, 569-596.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective On Learning And Innovation. Administrative Science Quarterly, *35* (1), 128-153.

Collins, C. (2000). Strategic human resource practices and the development of organizational social capital. Academy of Management Conference Presentation Toronto.

Conner, K. R., & Prahalad, C. K. (1996). A resource-based theory of the firm: Knowledge versus opportunism. Organization Science, *7* (5), 477-501.

Crossan, M. M., Lane, H. W., & White, R. E. (1999). An organizational learning framework: From intuition to institution. Academy of Management Review, *24* (3), 522-537.

Darr, E. D., & Kurtzberg, T.R. (2000). An investigation of partner similarity dimensions on knowledge transfer. Organizational Behavior and Human Decision Processes, *82* (1), 28-44.

Darr, E. D., Argote, L., & Epple, D. (1995). The acquisition, transfer and depreciation of knowledge in service organizations: Productivity in franchises. Management Science, *41*, 1750-1762.

Deeds, D.L. (in press). Alternative strategies for knowledge-based competition: Acquiring knowledge from beyond the boundaries. In S. Jackson, M. Hitt, and A. DeNisi (eds.). Managing knowledge for sustained competitive advantage: Designing strategies for effective human resource management.

DeNisi, A., Hitt, M. & Jackson, S. (in press). The knowledge-based approach to sustainable competitive advantage. In S. Jackson, M. Hitt, and A. DeNisi (eds.). Managing knowledge for sustained competitive advantage: Designing strategies for effective human resource management.

- Deng, Z. Lev, B. & Narin, F. (1999). Science and technology as predictors of stock performance. Financial Analysts Journal, 55 (5) May/June 20-32.
- DiFrancesco, J. M., & Berman, S. J. (2000). Human productivity: The new American frontier. National Productivity Review, 19 (3), 29-37.
- Dodgson, M. (1993). Organizational learning: A review of some literatures. Organization Studies, 14 (3), 375-394.
- Downes, M., & Thomas, A. S. (2000). Knowledge transfer through expatriation: The u-curve approach to overseas staffing. Journal of Managerial Issues, 12 (2), 131-149.
- Dussauge, P., Garrette, B., & Mitchell, W. (2000). Learning from competing partners: Outcomes and durations of scale and link alliances in Europe, North America and Asia. Strategic Management Journal, 21 (2), 99-126.
- Dyer, J., & Nobeoka, K (2000). Creating and managing a high performance knowledge sharing network: The Toyota case. Strategic Management Journal, 21, 345-367.
- Dzinkowski, R. (1999). Managing the brain trust. CMA Management, 73, 14-18.
- Dzinkowski, R. (2000). The measurement and management of intellectual capital: An introduction. Management Accounting, 78, 32-36.
- Economist, (1998). A Viking with a compass, 347, 64, June 6.
- Edvinsson, L. & Malone, M. (1997). Intellectual capital. Cambridge, MA: Harvard Business School Press.
- Epple, D., Argote, L., Devedas, R. (1991). Organizational learning curves: A method for investigating intra-planet transfer of knowledge acquired through learning by doing. Organization Science, 2 (1), 58-71.
- Epple, D., Argote, L. & Murphy, K. (1996). An empirical investigation of the microstructure of knowledge acquisition and transfer through learning by doing. Operations Research, 44 (1), 77-87.
- Evans, P., & Wurster, T. S. (1998). Strategy and the new economics of information. Harvard Business Review, 75, 70-83.
- Evans, P., & Wurster, T. S. (November/December, 1999). Getting real about virtual commerce. Harvard Business Review. 85-94.
- Fiol, C.M. (in press). Designing knowledge work for competitiveness: About pipelines and rivers. In S. Jackson, M. Hitt, and A. DeNisi (eds.). Managing knowledge for sustained competitive advantage: Designing strategies for effective human resource management.
- Fiol, C. M., Y Lyles, M. (1985). Organizational learning. Academy of Management Review, 10 (4), 803-813.
- Fisher, S. R. & White, M. A. (2000). Downsizing in a learning organization: Are there hidden costs? Academy of Management Review, 21 (1), 244-251
- Flamholtz, E.G. (1999). Human Resource Accounting (3rd ed.). Boston, MA: Kluwer.
- Glaeser, E.L., Laibson, D.I., Scheinkman, J.A., and Soutter, C.L. (2000). Measuring trust. The Quarterly Journal of Economics, 115, (3) 811-847.
- Grannovetter, M. (1973). The strength of weak ties. American Journal of Sociology, 6, 1360-1380.
- Gruenfeld, D. H., Martorana, P. V., & Fan, E. T. (2000). What do groups learn from their worldliest members? Direct and indirect influence in dynamic teams. Organizational Behavior and Human Decision Processes, 82 (1) 45-59.
- Gupta, AK & Govindarajan, V. (2000). Knowledge flows within multinational corporations. Strategic Management Journal, 21, 473-496.
- Hackett, B. (March, 2000). Beyond knowledge management: New ways to work and learn. New York: Conference Board.
- Hage, J., & Hollingsworth, J. R. (2000). A strategy for the analysis of idea innovation networks and institutions. Organization Studies, 21 (5), 971-1004.
- Hall, B., Jaffe, A., & Trajtenberg, M. (2000). Market value and patent citations: A first look. NBER Working Paper No. 7741.

- Hansen, M. T. (1999). The search-transfer problem: The role of weak ties in sharing knowledge across organizational subunits. *Administrative Science Quarterly*, *44*, 82-111.
- Helfat, C. E. (1997). Know-how and asset complementarity and dynamic capability accumulation: The case of R&D. *Strategic Management Journal*, *18* (5), 339-360.
- Hitt, M., A., Dacin, M. T., Levitas, E., Arregle, J. L., & Borza, A. (2000). Partner Selection in emerging and developed market contexts: Resource based and organizational learning perspectives. *Academy of Management Journal*, *43* (3), 449-467.
- Hoopes, D. G., & Postrel, S. (1999). Shared knowledge, glitches and product development performance. *Strategic Management Journal*, *20*, 837-865.
- Ingram, P. & Baum, J. A. (1997). Opportunity and constraint: Organizations' learning from the operating and competitive experience of industries. *Strategic Management Journal*, *18* (Special issue), 75-98.
- Inkpen, A. C., & Dinur, A. (1998). Knowledge management processes and international joint ventures. *Organization Science*, *9* (4), 454-479.
- Jaffe, A. B. (1986). Technological opportunity and spillovers of R&D: Evidence from firms' patents, profits and market value. *American Economic Review*, *76* (5), 984-1001.
- Jaffe, A. B., Trajtenberg, M., & Fogarty, M. S. (2001). Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors. National Bureau of Economic Research Working Paper.
- Knack, S. & Keefer, P. (1997). Does social capital have an economic payoff? A cross-country investigation. *The Quarterly Journal of Economics*, *112* (4) 1251-1288.
- Kogut, B., & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, *3* (3), 383-397.
- Kogut, B. (2000). The network as knowledge: Generative rules and the emergence of structure. *Strategic Management Journal*, *21*, 405-425.
- Lado, A.A., & Wilson, M.C. (1994). Human resource systems and sustained competitive advantage: A competency-based perspective. *Academy of Management Review*, *19* (4), 699-727.
- Lam, A. (2000). Tacit knowledge, organizational learning and societal institutions: an integrated framework. *Organization Studies*, *21* (3), 487-513.
- Lane, P. J., & Lubatkin, M. (1998). Relative absorptive capacity and interorganizational learning. *Strategic Management Journal*, *19*, 461-477.
- Lawson, C., & Lorenz, E. (1999). Collective learning, tacit knowledge and regional innovative capacity. *Regional Studies*, *33* (4), 305-317.
- Leigh, D. E., & Gifford, K. D. (1999). Workplace transformation and worker upskilling: The perspective of individual workers. *Industrial Relations*, *38* (2), 174-191.
- Lev, B., & Zarowin, P. (1999). The boundaries of financial reporting and how to extend them. *Journal of Accounting Research*, *37* (2), 353-383.
- Levine, J. M., Higgins, E. T., & Choi, H. (2000). Development of strategic norms in groups. *Organizational Behavior and Human Decision Processes*, *82* (1), 88-101.
- Lewis, E. E. & Lippitt, J. W. (1999). Valuing intellectual assets. *Journal of Legal Economics*, *9*, 31-48.
- Locke, E.A. (1999). Some reservations about social capital. *Academy of Management Review*, *24*, (1), 8-11.
- Low, J. & Siesfeld, T. (1998). Measures that matter. *Strategy and Leadership*, *26* (2), 24-29, March/April.
- Lynn, B. (1998). Intellectual capital. *CMA Magazine*, *72*, 10-15.
- Maskell, P. & Malmberg, A. (1999). Localized learning and industrial competitiveness. *Cambridge Journal of Economics*, *23*, 167-185.
- McEvily, B., & Zaheer, A. (1999). Bridging ties: A source of firm heterogeneity in competitive capabilities. *Strategic Management Journal*, *20*, 1133-1156.
- Mintz, S. L. (February, 1999). Seeing is believing. *CFO Magazine*, *15* (2), 29-34.

Moreland, R. L., Argote, L., & Krishnan, R. (1996). Socially shared cognition at work: Transactive memory and group performance. In J. L. Nye & A. M. Brower (Eds.), What's social about social cognition? Research on socially shared cognition in small groups. 57-84. Thousand Parks, CA.: Sage.

Moreland, R.L., & Myaskovsky, L. (2000). Exploring the performance benefits of group training: Transactive memory or improved communication? Organizational Behavior and Human Decision Processes, 82, 117–133.

Mowery, D.C., Oxley, & Silverman (1996). Strategic alliances and interfirm knowledge transfer. Strategic Management Journal, 17 (Winter Special Issue), 77-91.

Nahapiet, J. & Ghosal, S., (1998). Social capital, intellectual capital, and the organizational advantage. Academy of Management Review, 23 (2), 242-266.

Osterland, A. (April 1, 2001). Decoding intangibles. CFO. 57-62.

Paulus, P. B., & Yang, H. (2000). Idea generation in groups: A basis for creativity in organizations. Organizational Behavior and Human Decision Processes, 82, 76-87.

Petrash, G. (1996). Dow's journey to a knowledge value management culture. European Management Journal, 14, (4), 365-373.

Pfeffer, J. & Sutton, R.I. 2001. *The knowing-doing gap: How smart companies turn knowledge into action*. Boston, MA: Harvard Business School Press.

Polanyi, S. (1966). The Tacit Dimension. New York: Doubleday & Co.

Powell, W. W., Koput, K W., & Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. Administrative Science Quarterly, 41 (1), 116-136.

Rayport, J. E., & Sviokla, J. J. (Nov/Dec, 1995). Exploiting the Virtual Value Chain. Harvard Business Review, 73, 75-86.

Roos, J. & von Krogh, G. (1996). The epistemological challenge: Managing knowledge and intellectual capital. European Management Journal, 14 (4), 333-337.

Roslender, R. (2000). Accounting for intellectual capital: A contemporary management accounting perspective. Management Accounting, 78, 34-37.

Rothermael, F and Deeds, D. (2001). More good things are not necessarily better: an empirical study of strategic alliances, experience effects and innovative output in high technology startups. Working paper.

Seely-Brown, J. & Duguid, P. (May/June, 2000). Balancing act: How to capture knowledge without killing it. Harvard Business Review, 78 (3), 73-80.

Sherif, M. (1936). The psychology of social norms. New York: Harper.

Shenkar, O., & Li, J. (1999). Knowledge search in international cooperative ventures. Organization Science, 10 (2): 134-143.

Simonin, B. L. (1997). The importance of collaborative know-how: An empirical test of the learning organization. Academy of Management Journal, 5 (40), 1150-1174.

Simonin, B. L. (1999). Ambiguity and the process of knowledge transfer in strategic alliances. Strategic Management Journal, 20, 595-623.

Sjoholm, F. (1996). International transfer of knowledge: The role of international trade and geographic proximity. Welwirtschaftliches Archives, 132, 97-115.

Skandia Corporation (1996). Power of Innovation Skandia Navigator. Supplement to Skandia's 1996 Interim Report.

Sorensen, J.B. & Stuart, T.E. (2000). Aging, obsolescence and organizational innovation. Administrative Science Quarterly, 45 (1), 81-112

Spencer, J. (2000). Knowledge flows in the global innovation system: Do US firms share more scientific knowledge than their Japanese Rivals? Journal of International Business Studies, 31 (3), 521-531.

Spender, J.C. (1996). Making knowledge the basis of a dynamic theory of the firm. Strategic Management Journal, 17 (Winter) 5-9.

Stasser, G., Vaughn, S. I., & Stewart, D. D. (2000). Pooling unshared information: The benefits of knowing how access to information is distributed among group members. Organizational Behavior and Human Decision Processes, 82 (1), 102-116.

Stewart, T. (1998). Intellectual Capital : The New Wealth of Organizations. New York: Doubleday.

Subramaniam, M. & Venkatraman, N. (2001). Determinants of Transnational New Product Development Capability: Testing the influence of transferring and deploying tacit overseas knowledge. Strategic Management Journal, 22 (4), 359-78.

Sveiby, K.E. (1997), The New Organizational Wealth. San Francisco: Barrett-Koehler.

Tan, H., & Libby, R. (1997). Tacit managerial knowledge versus technical knowledge as determinants of audit performance in the field. Journal of Accounting Research, 35, 97-113.

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. Strategic Management Journal, 18 (7), 509-533.

Tomlinson, M. (1999). The learning economy and embodied knowledge flows in Great Britain. Journal of Evolutionary Economics, 9 (4), 431-452.

Torstensson, R. M. (1999). Growth, knowledge transfer and European integration Applied Economics, 31 (1), 97-106.

Van den Bosch, F. A. J., Volberda, H. W., & de Boer, M. (1999). The meaning of patent citations: Report of the NBER/Case Western Reserve Survey of Patentees. Washington, D.C: National Bureau of Economic Research.

van Meijl, H., & van Tongeren, F. (1999). Endogenous International Technology Spillovers and Biased Technical Change. Agriculture Economic Systems Research, 11 (1), 31-48.

Walsh, J. P. & Ungson, G. R. (1991). Organizational Memory. Academy of Management Review, 16, 57-91.

Wasserman, S., & Faust, K. (1994). Social Network Analysis: Methods and Applications. Cambridge, UK: Cambridge University Press.

Weick, K., & Roberts, K. (1993). Collective mind in organizations: Heedful interrelating on flight decks," Administrative Science Quarterly, 38, 357-381.

Zahra, S. A., Ireland, R. D. & Hitt, M. A. (2000). International expansion by new venture firms: International diversity, mode of market entry, technological learning, and performance. Academy of Management Journal, 43 (5), 925-950.

Zander, U., & Kogut, B. (1995). Knowledge and the speed of the transfer and imitation of organization capabilities: An empirical test. Organization Science, 6 (1), 76-92.

About the Author

John W. Boudreau, Ph.D., Professor of human resource studies at Cornell University is recognized worldwide for breakthrough research on the bridge between superior human capital, talent and sustainable competitive advantage. His research has received the Academy of Management's Organizational Behavior New Concept and Human Resource Scholarly Contribution awards. Dr. Boudreau consults and conducts executive development with companies worldwide that seek to maximize their employees' effectiveness by quantifying the strategic bottom-line impact of superior people and human capital strategies, including Boeing, Bristol-Myers Squibb, Citigroup, GE, IBM, JP Morgan Chase, Novartis, Schering-Plough, Shell International, Sun Microsystems, Transamerica, the United Nations, Verizon, and Williams-Sonoma. Professor Boudreau was an architect and the first Visiting Director of Sun Microsystems' unique Research and Development Laboratory for Human Capital. Professor Boudreau is a Fellow of the National Academy of Human Resources.

Dr. Boudreau has published more than 40 books and articles, including the best-selling *Human Resource Management* (Irwin: 1997), now in its eighth edition in multiple languages worldwide. In addition to HR metrics, Dr. Boudreau's large-scale research studies and highly focused qualitative research have addressed decision-based HR, executive mobility, HR information systems and organizational staffing and development. His research findings have been published in *Management Science*, *Academy of Management Executive*, *Journal of Applied Psychology*, *Organizational Behavior and Human Decision Processes*, *Personnel Psychology*, *Asia-Pacific Human Resource Management*, *Human Resource Management*, *Journal of Vocational Behavior*, *Human Relations*, *Industrial Relations*, *Journal of Human Resources Costing and Accounting*, and *Personnel Administrator*.

Features on his work have appeared in *The Wall Street Journal*, *Fortune*, *Business Week*, *Training*, and *Human Resources Management*.

The winner of the General Mills Award for teaching innovations, Dr. Boudreau also founded the Central Europe Human Resource Education Initiative, which links American HR professionals and academic researchers with faculty and students in the Czech and Slovak Republics. A strong proponent of corporate/academic partnerships, Dr. Boudreau directed the Center for Advanced Human Resource Studies (CAHRS), which partners executives from America's top corporations with university researchers and students to explore leading-edge HR issues. This Cornell University "think tank" has generated groundbreaking insights and practical solutions for the human resource challenges that affect most organizations today.

Dr. Boudreau is a member of the board of advisors for Brassring.com, a technology information and career portal. He chaired the Academic Advisory Board of the California Strategic HR Partnership, a silicon-valley HR executive consortium, Saratoga Institute, a leading global source of human capital benchmarking and performance measures; and Primelearning.com, which provides performance-based business and professional skills training over the Internet. He has also been elected to the executive committees of the Human Resources Division of the Academy of Management and the Society for Industrial and Organizational Psychology. Dr. Boudreau holds an undergraduate degree in business from New Mexico State University, and a Masters degree in Management and Ph.D. in industrial relations from Purdue University's Krannert School of Management.