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COMPLEMENTARITIES BETWEEN INFORMATION TECHNOLOGY AND HUMAN RESOURCE PRACTICES IN KNOWLEDGE WORK

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Abstract

We present a theoretical framework of Human Resources (HR) and Information Technology (IT) alignment, and validate this framework empirically. First, we present a system of HR-related work practices (facilitating HR) and system of IT-related practices (facilitating IT) that are specific to knowledge workers. We examine the interaction between facilitating HR practices and facilitating IT practices in the productivity outcomes of firms in knowledge-intensive industries. Next, we examine the quantitative firm productivity impacts of IT investment and facilitating HR-related work practices in the context of a specific type of knowledge work: the work of IT professionals. Linking separate datasets, we utilize both objective economic metrics and managers' subjective assessments of firm productivity improvements in order to assess the effect of HR-IT alignment on firm productivity.

Keywords: Information Technology, Human Resources, Knowledge Work, Productivity, IT professionals, Alignment, Governance

Introduction

Information Technology (IT) has improved workers' ability to collaborate, access information, and make decisions autonomously. These and other aspects of knowledge work—self-directed work involving high information content— have become central to the growth of the economy (Becker 1962; Drucker 1999; Rai and Sambamurthy 2006; Straub and Karahanna 1998). Therefore, it is important to understand how Human Resources (HR) practices must evolve to align with new IT capabilities and the implications of such HR-IT alignment for firm performance.

In this paper, we present a theoretical framework of HR and IT alignment, and validate this framework empirically. First, we draw from previous literature on the economics of HR to describe a system of HR-related work practices (facilitating HR) and system of IT-related practices (facilitating IT) that are specific to knowledge workers. We examine the interaction between facilitating HR practices and facilitating IT practices in the productivity outcomes of firms in knowledge-intensive industries. Next, we examine quantitative firm productivity impacts of IT investment and facilitating HR practices in the context of a specific type of knowledge work: the work of IT professionals. We use both objective economic metrics and managers' subjective assessments of firm productivity improvements.

Background Literature

Drawing on prior work (Tafti, Mithas and Krishnan 2007), we briefly review the following two streams of the background literature that provide a foundation for our study.

The Relationship between HR and IT in Knowledge Work

The digitization of business processes has led to greater complexity and visibility of information, resulting in a greater demand for knowledge-intensive labor (Bresnahan, Brynjolfsson and Hitt 2002; Levy and Murnane 2004; Zuboff 1988). Such knowledge-intensive labor requires worker autonomy, information seeking, and interpersonal collaboration (Davenport 2005; Drucker 1999). When firms and employees adapt to new IT, they also change their organizational routines, work processes, and work habits (Bresnahan et al. 2002; Levy and Murnane 2004). IT enhances collaboration and coordination among knowledge workers who might otherwise be separated by geographical, departmental or organizational boundaries (Apte and Mason 1995; Mithas and Whitaker 2007; Ramasubbu et al. 2007b).

Theoretical arguments from previous literature, as well as some practical or anecdotal examples, support the idea that HR and IT practices can be complementary. Milgrom and Roberts (1995), Baker, Gibbons, and Murphy (1994), and Holmstrom and Milgrom (1994) develop some of the analytical underpinnings of strategic complementarities. Among empirical studies on the relationship between IT and HR, Bresnahan et al. (2002) find that IT investment accompanied by work reorganization investments and a more highly skilled workforce contribute to firm-level productivity. Autor, Levy, and Murnane (2003) show that the complementarity between HR practices and IT investment is driven by the fact that IT is a lower-cost substitute for routine labor, thereby increasing the demand for non-routine labor and a more educated workforce. Powell and Dent-Micallef (1997) examine the relationship between IT and HR practices, taking the perspective that IT is a technological resource that leverages other firm resources.

While the complementary interaction of innovative HR work practices and IT investment on firm productivity has been documented (Bresnahan et al. 2002), the underlying mechanisms for such complementarity still remain unexplained. This paper examines the complementarity between IT and HR at a consistent level of analysis, that is, at the level of work practices to understand how *specific* IT-related practices implemented together with innovative HR practices affect firm-level productivity. Specific IT practices such as the support of knowledge-repositories, instant-messaging, and other collaborative tools and their role as complements to HR practices may be particularly important in knowledge-intensive industries where employees tend to spend more time working with computers. Building on the empirical literature on HR and IT complementarities, we examine whether such IT practices are complementary to HR practices in their effects on productivity of firms in knowledge-intensive industries.

HR Practices and IT Professionals

We consider a specific type of knowledge worker—the IT professional. Because of their proximity to the day to day operations of the firm, IT professionals are well positioned to initiate many technical and business process innovations (Daft 1978; Swanson 1994). In particular, the work of IT professionals often involves managerial competencies associated with the successful planning, implementation, and deployment of IT systems or of IT integration (Agarwal and Ferratt 1999; Ferratt et al. 2005; Josefek and Kauffman 2003; Mithas and Krishnan 2007). Their task of applying IT to solve business problems, requiring the ability to coordinate between multifaceted activities at the interface between technology and business processes, represents a form of knowledge work in which significant returns to tertiary education have been documented (Ang, Slaughter and Ng 2002; Levina and Xin 2007; Mithas and Krishnan 2007). Firms can encourage IT-related innovation by engaging in HR practices that encourage creativity, autonomy, and knowledge exchange at the interface between business and technology (Ambrose, Ramaprasad and Rai 1998; Lee, Trauth and Farwell 1995; Leonard-Barton and Deschamps 1988; Mithas and Krishnan 2007; Zmud 1984).

Due to the pivotal role of IT professionals at the interface of technology and business, there has been substantial interest in the particular HR-related issues that pertain to IT professionals. For example, Mithas and Krishnan (2007) examine the human capital and institutional factors related to the compensation of IT professionals, focusing on the returns to an MBA degree and IT-related experience. Ang and Slaughter (2002) find a correlation between education of IT workers and their compensation levels. Josefek and Kaufmann (2003) utilize human capital theory from economics to identify precursors of IS professionals' intentions to leave or stay with their firms. Igarria, Greenhaus, and Parasuraman (1991) identify two major paths of development of IT professionals: technical and managerial, and find that job satisfaction of IT professionals is determined by the alignment of personal orientations with the job track. We seek to contribute to this line of research by considering whether such HR-related practices for IT professionals, such as compensation and career development opportunities, enhance a firm's ability to derive value from IT investments.

Theory and Hypotheses

Drawing upon prior theory (Adler and Borys 1996; Ichniowski, Shaw and Prenzushi 1997; Miles, Snow and Meyer 1978), we posit two distinct forms of HR management practices (Tafti et al. 2007): traditional HR management and innovative HR management. While traditional HR management views managers as controllers and monitors of workers, innovative HR management views managers primarily as *facilitators*, in that their role is to remove “the constraints that block organization members' search for ways to contribute meaningfully to their work roles” (Miles et al. 1978 p. 560). The concept of “facilitation” aligns with innovative HR management because it implies the removal or reduction of barriers, such as barriers to sources of information or barriers between people or functional units within a firm (Tafti et al. 2007).

Adler and Borys (1996) describe three features of enabling management practices that are useful in our description of facilitating practices. First, facilitating practices provide employees with visibility into local processes, those with which employees are directly involved, enabling workers to repair problems as they arise. Second, these practices give employees greater visibility into the “broader system within which they are working”, enabling employees to find opportunities for improvement and to provide suggestions to management (Adler and Borys, 1996 p. 73). Third, both on a small and large scale, these practices give workers more flexibility to initiate changes in business processes. Central to the distinction by Adler and Borys (1996) between enabling and coercive methods of management is whether or not the worker is being empowered to fully leverage his/her capabilities, which is possible when employees have visibility into firm processes and when the firm is adaptable to engage and respond to employees' insights.

Characterizing Facilitating HR Practices

We discuss here each of the practices that comprise a facilitating HR policy, and how each practice interacts with other practices to contribute to firm performance, thereby forming a system. The idea that individual HR practices interact together as a system is developed in Ichniowski et al. (1997), Black and Lynch (2001), and Bresnahan et al. (2002). Facilitating HR entails the following conditions: (1) It encourages worker autonomy, (2) it fosters connectedness among workers through collaboration and information sharing, (3) it fosters a culture of learning in

the organization, (4) it fosters a culture of valuing individuals, (5) it fosters an environment of trust, and (6) it promotes greater flexibility in work structures.

Worker autonomy can be created through flexible work structures, giving employees greater control over their own schedules, and through sharing of information between managers and workers. Autonomous workers are better able to collaborate across organizational boundaries and to develop an understanding of processes beyond their narrowly defined job descriptions (Kang, Morris and Snell 2007). Autonomous workers are also more likely to engage in creative or exploratory activities that lead to innovation (Ahuja and Thatcher 2005; Drucker 1999; Kang et al. 2007; Leonard-Barton 1992).

Collaboration and information sharing can be implemented through self-managed teams, management policies that reduce inter-personal rivalry, and incentives based on group rather than individual output. Collaboration helps create synergies among the talents of people in a firm and encourages creative problem solving (Drucker 1999), and is an effective way to transfer idiosyncratic or tacit knowledge (Brown and Duguid 1991; Davenport 2005; Kang et al. 2007). Effective collaboration requires worker autonomy and flexible work structures, as workers will have greater freedom to access a more diverse base of knowledge and to form connections within and across firm boundaries (Hargadon and Sutton 1997; Leonard-Barton 1992). In order to collaborate and share information, there needs to be a sense of reciprocity founded on mutual trust, the absence of which would compromise the sharing of knowledge (Hargadon and Sutton 1997).

The *culture of learning* can be created by providing formal training programs, by encouraging employees to share knowledge, by implementing cross-training of skills, and by providing employees access to potentially useful information (e.g., technical reports, educational materials). A culture of learning enables employees to grow professionally and to learn new skills, including those that extend their capabilities beyond the boundaries of a narrow job description (Senge 1990). Hence, a culture of learning is complementary to creating flexible work structures (Kang et al. 2007; Leonard-Barton 1992; Milgrom and Roberts 1990). Also, by training workers, the firm is sending a signal to employees that they are valued and hence their job is secure (Mithas and Krishnan 2007). Developing a culture of learning is particularly critical in the context of knowledge work (Drucker, 1999).

The culture of *valuing individuals* can be created by making employees feel more secure in their jobs, and implementing benefits the result in reduced stress. Such benefits can include, but are not limited to: (1) flextime, on-site day care, and extended leaves, (2) improvement of ergonomics for workers, (3) boosting pay above the cost of living, (4) re-deploying, rather than laying off, employees in case of changing demand for labor, (5) careful selection of employees for cultural fit as well as performance potential, which increases the likelihood that employees who enter the firm will stay. Research suggests that reducing the levels of stress and strain on employees is conducive to worker performance: "Individuals who feel greater conflict or overload perform at lower levels" (Ahuja and Thatcher 2005 p. 432). Firms can further re-assure employees of job security by training employees for multiple-work roles that extend beyond their narrow job descriptions, and providing flexible work structures that enable employee redeployment when it is necessary (Ichniowski et al. 1997). This set of practices creates an environment where employees are more comfortable in providing suggestions to management without the fear that efficiency improvements will result in job cuts (Baker et al. 1994).

The culture of trust is established through practices that also contribute to several of the other dimensions of facilitating HR (Adler, Goldoftas and Levine 1999). For example, employees develop greater trust when working together in teams and through frequent interaction (Cramton 2001; Handy 1995; Olson and Olson 2000). Trust increases the effectiveness of collaboration (Cramton 2001). Trust is related to worker autonomy, because autonomous workers need to be trusted to allocate their time wisely, and to make decisions that benefit the firm.

Flexible work structures can be created through flexible job assignments, rotating employees through different functional areas, providing cross-training of skills beyond employees' job descriptions, and rapidly redeploying employees in case of sudden changes in market conditions. In flexible work structures, employees develop not only a deep knowledge of their own task domains but also become familiar with the interfaces between their task domains and others' (Adler et al. 1999). Hence, employees' knowledge broadens, enabling them to provide suggestions that contribute to the firm's productivity (Adler and Borys 1996; Ichniowski et al. 1997). By giving employees the resources to learn new skills and opportunities to apply these skills to different business functions, firms can respond more quickly to changes in their market environment by realigning their internal operations. Work-structure flexibility makes employees feel more valued by increasing the number of ways in which employees' skills can be put to use, a condition called "resource flexibility" (Wright and Snell 1991), and increasing employees' sense of belonging in the firm.

Incentives can be an integral part of facilitating HR because they motivate employees to work hard; but they must be designed in such a way as to complement rather than undermine workers' incentive to cooperate with each other. For example, group-based incentives foster cooperation and collaboration. However, a challenge in designing such incentives is that employees can free-ride on the efforts of others (Baker et al. 1994; Kandel and Lazear 1992). To mitigate this, such incentives should be accompanied by other facilitating HR practices. Firms can create a team spirit, and strengthen it through practices that foster trust and make individuals feel valued (Baker et al. 1994; Kandel and Lazear 1992). The alignment of the organization's goals with those of the employees is critical for a facilitating HR policy (Adler and Borys 1996).

Characterizing Facilitating IT Practices

Specific IT practices can complement the facilitating HR practices described above—we call these *facilitating IT* practices. These facilitate employee collaboration, autonomy, and wider access to information. Such IT practices stand in contrast to *monitoring IT practices*, in which IT is used primarily as a tool to monitor workers (Tafti et al. 2007). Facilitating IT includes mobile access to data and business applications. It also includes support of Instant Messaging (IM) applications, which enable employees to connect with one another and collaborate at a distance. Researchers have found that the use of IM helps build connectedness and trust among employees, especially among those who use IM to engage in informal conversation while doing substantive work of a collaborative nature (Bos et al. 2002; Moore et al. 1999; Zheng et al. 2002). This facilitates knowledge sharing across functional units. Other collaborative software tools, such as issue-tracking tools, distributed project software, and document source repositories, also facilitate knowledge sharing and information access (Grudin 1994; Tafti et al. 2007).

Knowledge management tools can be instrumental in enabling knowledge sharing across a company (Alavi and Leidner 2001). For example, document repositories or archived case reports allow employees to strengthen their expertise in their own task-specific domains, and also to learn about how their jobs interface with other task or knowledge domains (Kang et al. 2007; Takeishi 2002). This makes employees more self-sufficient, and enables them to be redeployed to other functional areas if the need arises, thus complementing a flexible work structure. However, a knowledge management system is effective only to the extent that employees take the time to contribute information, which requires a culture that rewards information sharing and that encourages creative or exploratory behavior (Ahuja and Thatcher 2005; Kankanhalli, Tan and Kwok-Kee 2005). Employees are sometimes made to feel replaceable when their knowledge is codified and made readily available to others. Firms can mitigate this by implementing practices that make employees feel valued and secure in their jobs (Baker et al. 1994).

Firm Performance Implications of Facilitating HR and IT in Knowledge-Intensive Industries

Our foregoing discussion leads to two conclusions. First, as data and information become widely accessible within the organization, their value is more likely to be realized when employees are empowered to leverage the capabilities of IT. We suggest that the attempt to implement a facilitating HR strategy in an environment that lacks facilitating IT practices would be self-defeating, since it can have a demoralizing effect on workers that could lead to a disruption or breaking down of the facilitating HR environment. Likewise, the attempt to implement a facilitating IT strategy in an environment that lacks facilitating HR practices would be self-defeating. Hence, we suggest that facilitating HR and facilitating IT practices are complementary, particularly in knowledge-intensive industries where employees have greater exposure to computers (Mithas and Whitaker 2007; Tafti et al. 2007). Thus,

H1: Facilitating HR practices and facilitating IT practices are complementary in their contribution to firm productivity in knowledge-intensive industries.

Next, we apply this theoretical framework to a specific type of knowledge work.

Firm Performance Implications of IT investment and Facilitating HR for IT Professionals

By applying the above theoretical framework to a specific class of knowledge work, we are better able to describe the mechanisms that link HR and IT policies to firm performance. Since IT integrates various business functions, the IT professional must be knowledgeable of how information and business processes cross the various business functions (Bassellier and Benbasat 2004; Mithas and Krishnan 2007; Smaltz, Sambamurthy and Agarwal 2006). Because much of the required business knowledge is tacit, the IT professional must often form interpersonal connections in order to solve problems that cross various business domains. In addition, the IT professional is in a

position to recognize opportunities for innovation in business processes. Problems at the intersection of IT and business are often complex, requiring creativity, collaboration and a mix of business and technology skills. Since facilitating HR practices are designed to leverage the skills of the IT professional, such practices enable firms to derive greater value from their investments in IT. We hypothesize:

H2: Facilitating HR practices for IT professionals positively moderate the effect of IT investment on firm productivity.

Research Design and Methodology

We utilize two estimation models using two separate but related datasets to test our hypotheses by combining survey data with archival data from other sources. The survey data comes from senior IT managers, vice presidents, e-commerce directors, and C-level executives.

Estimation Model 1: Complementarities between HR and IT Practices

To test H1, we draw from an Optimize Magazine survey which was conducted in 2004 in order to investigate how IT influences worker productivity. Managers were asked questions regarding both technology and non-technology steps taken to enhance worker productivity. Respondents were also asked to assess the level of productivity improvement in their organizations.

H1 pertains to firms in high knowledge-intensive industries. One measure of industry-level knowledge-intensity, used in prior research, is the level of an industry's reliance upon educated workers (Coff 1999).¹ While years of schooling does not capture all informal training or knowledge work, particularly for tasks requiring industry or firm-specific tacit knowledge, it is a common measure of human capital representing knowledge that is general, explicit, and codified (Becker and Chiswick 1966). Prior research indicates that tacit and explicit forms of knowledge are not mutually exclusive, because knowledge obtained through schooling is often a basis for developing tacit or firm-specific knowledge (Helfat 1994). Therefore, quality of education is often used by firms in knowledge-intensive industries as a signal of employee aptitude (Arrow 1974; Coff 1999; Helfat 1994).

The Bureau of Labor Statistics (BLS) presents a classification system for the level of education of employees in each industry, in a section entitled "Educational and Training Classifications"² published in the handbook *BLS Occupational Projections and Training Data (2006-07)*. BLS defines six clusters, which we rank as levels 1 (lowest) through 6 (highest), depending on the percentage of employees having attained high school, some college education (including Associates degrees), or Bachelors degree. We chose the ranking level of 4 or above as a cutoff-level for industries that we designated as highly knowledge-intensive. At level 4, at least 20% of employees have a Bachelor's degree or higher, and an additional 20% of employees have some college education. In the results section we describe the results of a test for structural break between high and low knowledge-intensive industries. Pending the confirmation of this structural break, our final sample for model 1 has 195 firms.

The dependent variable in this part of the study was managers' perceived increase in firm productivity (on a scale of 1 through 5) over a one-year period (*PROD*). Managers were asked to assess, on a five point scale, the extent to which their organizations' productivity improved over the course of the previous year. To verify the validity of the subjective assessment of increase in productivity, we identified 27 firms in the Optimize survey for which Compustat metrics were available. An ordinal logistic regression using the perceptual measure as the dependent variable and the same period increase in quantitative value-added as an independent variable (a measure of firm productivity, detailed in the Appendix) resulted in a positive coefficient estimate significant at $\alpha = 1\%$, providing confidence in the validity of the perceptual measure of performance. Hence, we found a correspondence between the perceptual measure and the quantitative measure of firm-productivity increases. The mean of the managers' assigned productivity score for this sub-sample of 27 firms, 2.85, was roughly the same as the mean of the remaining firms, at 2.88; suggesting that the sub-sample is representative.

¹ Mithas and Whitaker (2007) use a similar approach to define the skill level of an occupation.

² <http://www.bls.gov/emp/optd/home.htm>

The independent variables of interest include use of facilitating IT (*FACIT*), and facilitating HR (*FACHR*). *FACHR*, and *FACIT* are summative measures, and validation procedures for these measures are discussed in the Appendix. In order to facilitate interpretation of the constructs' direct effects, we centered the variables *FACHR* and *FACIT* around their means.³ We used dummy variables to control for various functional areas in which worker productivity was measured: manufacturing, services, information technology, knowledge work/analysis, and other functional areas. These are not mutually exclusive, as a firm may be tracking worker productivity in multiple functional areas. We also controlled for firm size (*SIZE*), and knowledge-intensity (*levels 4-6*).

Since the dependent variable is an ordinal value, we estimate an ordinal logit model as follows:

$$\log\left(\frac{\pi_1 + \dots + \pi_j}{\pi_{j+1} + \dots + \pi_5}\right) = \beta_{0j} + \beta_1 \text{FACHR} \times \text{FACIT} + \beta_2 \text{FACHR} + \beta_3 \text{FACIT} + \mathbf{X}_c \beta_c + \varepsilon \quad (1)$$

where \mathbf{X}_c is the matrix of control variables, and π_j represents the probability of observing a *PROD* level of *j*. This is a proportional odds model, which models the five-level ordinal outcome of productivity by splitting the probability space ($\pi_1 + \pi_2 + \dots + \pi_5 = 1$) at four different cut points to create five ordered categories. The model predicts the odds of being above each of the cut points.

Variable	1	2	3	4	Obs.	Mean	SD	Min	Max	
PROD	1	1.00			195	2.87	0.85	0	4	
KW	2	0.03	1.00		196	4.35	0.48	4	5	
FACHR	3	0.17	-0.16	1.00	196	4.38	2.00	0	8	
FACIT	4	0.10	-0.09	0.47	1.00	196	4.29	2.38	0	9

Estimation Model 2: Complementarities between IT investments and Facilitating HR Practices for IT Professionals

To test H2, we use 2003 survey results from InformationWeek (IWeek) magazine. We obtained the data related to HR-related practices for IT professionals and IT expenditure data, and linked this data to quantitative measures of firm performance and other industry and firm-level controls available in Compustat. While the original data set contained over 275 firms, our final sample includes approximately 110 firms for which the required data, including quantitative productivity metrics, were available to test H2. We utilized Cook's extreme value test in order to eliminate two outlying observations which were causing disproportionate influence on the model estimates. The final sample size for testing H2 contains 108 publicly-listed firms.

Table 2 provides correlations and summary statistics of variables. We present the variables here, and provide a more detailed explanation of variable construction in the Appendix.

The dependent variable for testing H2 was the log of value-added (*VA*), a measure of productivity calculated using procedures described in Bresnahan et al. (2002).

The main independent variables of interest for testing H2 are total firm IT Expenditure (*IT*) and facilitating HR (*FACHRITP*) practices for IT professionals, a summative measure for which validation procedures are discussed in the Appendix. In order to facilitate interpretation of coefficients, we centered the variable *FACHRITP* and the quantity $\log(IT)$ around their means. The control variables used in this part of the study include labor expenses (*L*), capital (*K*), Industry-level IT Capital Intensity (*ITCAPINTENS*), and industry segment dummies.

³ Mean-centering of variables does not change coefficient estimates of the interactive terms.

We adopted the production function framework presented in Bresnahan et al. (2002), which has the following formulation:

$$\log(VA) = \log(S - M) = f(L, K, IT, FACHRITP; \text{controls})$$

S is Sales. M is Materials. The dependent variable, $\log(VA)$, is a measure of firm-level productivity. L and K are, respectively, labor and capital. The term FACHRITP is a quantity representing facilitating HR-related practices, and IT represents total IT expenditure. We want to assess whether facilitating HR practices for IT professionals moderates the effect of IT expenditure on firm productivity. Therefore, the model specification is:

$$\log(VA_{i,t}) = \text{Constant} + \beta_1 \log(IT)_{i,t-1} + \beta_2 FACHRITP_{i,t-1} + \beta_3 \log(IT)_{i,t-1} \times FACHRITP_{i,t-1} + \beta_4 \log(L)_{i,t-1} + \beta_5 \log(K)_{i,t-1} + \beta_6 ITCAPINTENS_{i,t-1} + \sum_j \beta_j I_{j,i,t-1} + \varepsilon_{i,t-1} \quad (2)$$

Each term in $\sum_j I_{j,i,t-1}$ represents industry control dummy variables classified according to the procedures in Bresnahan, et al. (2002).

Variable	1	2	3	4	5	6	Obs.	Mean	SD	Min	Max	
$\log(VA_t)$	1	1.00					128	7.39	1.29	4.31	10.82	
$\log(IT)$	2	0.74	1.00				120	9.23	1.49	5.09	13.17	
Industry IT Cap.	3	-0.14	0.02	1.00			270	0.21	0.19	0.05	0.74	
FACHRITP	4	0.05	0.06	-0.10	1.00		278	2.33	3.97	0.00	10.00	
$\log(K)$	5	0.77	0.75	-0.19	0.13	1.00	120	7.12	1.54	3.97	11.62	
$\log(L)$	6	0.95	0.67	-0.10	-0.02	0.69	1.00	119	6.93	1.30	3.97	10.77

Results

Results: Complementarities between HR and IT Practices

We first test whether there is a structural break between high and low knowledge-intensive industries with regard to the application of model 1, as suggested by previous research linking IT and innovative work practices to the demand for educated workers (Autor et al. 2003; Bresnahan et al. 2002). We separated our original dataset into two subsamples based on the industry-level measure of knowledge-intensity. A Chow test allowing unequal variances confirms that there is a structural break between the low and high knowledge-intensity subsamples, rejecting at $\alpha=0.05$ the hypothesis that parameters for the two subsamples are the same. This confirms a structural difference between low and high knowledge-intensive industries, and based on this result we proceed with the high-knowledge industries for the remainder of analysis.

Results of the ordinal logit estimation of model 1 are presented in Table 3. Column (1) represents the model with no interactive term, and column (2) shows the full model including the interaction term. H1 predicts that the implementation of facilitating HR practices is complementary to facilitating IT practices in its effects on firm productivity.

Our estimation results reveal some interesting insights regarding the impacts of facilitating HR practices, facilitating IT practices, and their interaction. Note that we have mean-centered FACHR and FACIT in order to facilitate interpretation of the direct effects, a procedure that leaves the coefficient estimates of the interactive terms unchanged. The non-significant estimate for the coefficient β_2 in Table 3 indicates that facilitating HR (with facilitating IT held fixed at its mean value), has no statistically significant impact on firm productivity improvements, as perceived by managers in knowledge-intensive industries. While the estimate for β_2 is positive, it has a high standard error. Our results indicate little direct impact of facilitating IT on firm productivity (with

facilitating HR held fixed at its mean value). The coefficient estimate of β_3 is small and the estimate of its standard error is higher.

However, as predicted by H1, we find that there is a positive and significant effect of the interaction of FACHR and FACIT on productivity. As shown in column (2) of Table 3, the positive coefficient estimate β_1 of the interaction term FACHR \times FACIT is significant at $\alpha=0.10$. A likelihood ratio of the full model in column (2) over the nested model in column (1) is 3.27, and this represents a statistically significant improvement in the fit of the full interactive model at a significance level of $\alpha=0.10$. The use of the ordinal logit model enables us to describe the effect of this interaction in terms of a probability for firm productivity improvement. Specifically, an increase in facilitating HR by one unit is associated with an increase in the effect of a one-unit increase of facilitating IT on the odds of firm productivity improvement by a factor of $\exp(0.058) = 1.06$. Moreover, an increase in facilitating HR, by one standard deviation (std. dev. = 2.00), is associated with an increase in the effect of facilitating IT (std. dev. = 2.38) on the odds of firm productivity improvement by a factor of $\exp(0.058 \times 2.00 \times 2.38) = 1.32$, representing a 32% improvement in odds. The result suggests that facilitating HR and facilitating IT are complementary in their effects on firm productivity, such that the practice of facilitating HR increases the effectiveness of facilitating IT, and vice versa.

Table 3. Results of ordinal logit regression. Dependent variable is manager’s perceived increase in productivity (PER_INC). FACHR and FACIT are mean-centered. Standard errors in parentheses. Significant at *10%, **5%, and ***1% level for χ^2 tests. N=195.¹

Model	(1)	(2)
β_1 FACHR \times FACIT		0.058* (0.032)
β_2 FACHR	0.103 (0.083)	0.131 (0.086)
β_3 FACIT	-0.020 (0.072)	-0.023 (0.072)
β_4 SIZE	0.137* (0.081)	0.117 (0.083)
Log likelihood	-201.27	-199.42
LR	52.38	56.07
Prob > Chi-Sqr	0.000	0.000

1. Note that we controlled for dummy variables representing functional areas in which firms tracked worker productivity, and industry-level knowledge-intensity (see in Appendix: “Functional Areas in Measuring Worker Productivity”, “Knowledge-intensity”); estimates for these additional controls are not shown.

Results: Complementarities between IT investment and Facilitating HR Practices for IT Professionals

Table 4 shows the results of the production function model shown by equation 2 using an ordinary least squares (OLS) approach. White’s test and the Breusch-Pagan test indicated heteroskedasticity in the data; therefore Huber-White robust standard errors are shown in parentheses. The dependent variable in all models in this table is firm productivity for the subsequent year. By controlling for industry-level IT capital intensity, we differentiate the firm’s IT spending from what is common for the industry. Given the sample size, we observe very high R² (above 90%) and high F-statistics. High values of model fit and model significance, such as these, are to be expected in production function models, as seen in Black and Lynch (2001), Bresnahan et al. (2002), and Kudyba and Diwan (2002). Further examination reveals that the F-statistics drop by a factor of about 10 when the variable labor, which

is standard in production function models, is omitted. This is expected because, by definition, value-added is largely a combination of labor and profits.

Consistent with previous research, model estimates show that IT investment has a positive effect on firm productivity (Brynjolfsson and Hitt 1996; Brynjolfsson and Hitt 2003). Note that, as in the analysis of model 1, we have mean-centered the independent variables FACHRITP and the $\log(IT)$ in order to facilitate interpretation of direct effects. Controlling for FACHRITP and its interaction with IT, among other controls, we observe that each additional dollar of IT investment per year is associated with an increase of 0.074 in value-added, which is well within the order of magnitude of previous estimates of IT investment contributions to firm productivity (Bresnahan et al. 2002).

Table 4. OLS regression estimates with Huber-White standard errors. Dependent variable is $\log(VA_t)$. FACHRITP and $\log(IT)$ are mean-centered. Huber-White standard errors in parentheses. Standard errors in parentheses. Significant at *10%, **5%, and ***1% level for 2-tailed t-tests. N=108.

Model	(1)	(2) with interaction term
β_1 $\log(IT)$	0.108*** (0.037)	0.074** (0.032)
β_2 FACHRITP	0.005 (0.007)	0.007 (0.006)
β_3 $\log(IT) \times$ FACHRITP		0.015*** (0.004)
β_4 $\log(\text{Labor})$	0.787*** (0.042)	0.778*** (0.041)
β_5 $\log(\text{Capital})$	0.102*** (0.036)	0.127*** (0.036)
β_6 Industry-level IT Capital Intensity	0.018 (0.171)	-0.057 (0.161)
Constant	0.275 (0.244)	1.155*** (0.275)
F statistic	187.09	247.55
Prob > F	0.000	0.000
R-squared	0.948	0.957
Root MSE	0.300	0.271

We observe that, when IT investment is held at its mean value, facilitating HR practices for IT professionals have no direct association with firm productivity, as seen in the estimates for β_2 which are near zero when IT investment is held at its mean value.

H2 predicts that the facilitating HR practices for IT professionals has a positive moderating influence on the effect of IT investment on firm productivity. In column (2) of Table 4, the positive coefficient estimate of β_3 , significant at $\alpha=0.01$, indicates support for H2. The result shows that facilitating HR practices for IT professionals positively influence the effect of IT investment on firm productivity. Specifically, a one-unit increase in FACHRITP is associated with an increase of 0.015 in the effect of IT expenditure on firm value-added. This implies that an increase in FACHRITP, from its mean value to one unit above, increases the marginal effect of IT investment from 0.074 to 0.089. Hence, there is a positive complementary interaction of IT investment with facilitating HR practices.

The result is consistent with the findings in Bresnahan et al. (2002) that innovative work organization practices are complementary to IT investment in their effects on firm productivity. Our findings show this kind of complementary effect to exist in facilitating HR practices for IT professionals, and highlight the pivotal role of IT professionals in the effective deployment of IT systems.

Research Implications

Our results have several implications for the effect of alignment of HR and IT practices on firm performance. Prior research, in examining firm productivity outcomes of the interaction between HR and IT, had used aggregated constructs of IT capital investment (Bresnahan et al. 2002). One contribution of our study is to examine the interaction of *specific* IT practices with innovative HR work practices, and their complementary effects on firm productivity. Our results suggest that facilitating HR practices have no significant direct impact on firm productivity. Likewise, facilitating IT practices appear to have a noisy and non-statistically significant direct impact on firm productivity as perceived by managers. However, it appears that facilitating HR practices have a moderating impact—in that they positively influence the firm productivity impacts of facilitating IT practices. Hence, facilitating IT and facilitating HR practices are complementary in their contributions to firm productivity. Therefore, our work contributes to the literature on HR and IT complementarities, notably by Bresnahan et al. (2002) and Powell and Dent-Micallef (1997), to generate new insights about the role of specific IT practices and their complementarities with HR practices in knowledge-intensive industries.

Another contribution of our study is to generate new insights on the interaction between HR and IT in the context of a specific form of knowledge work—the work of IT professionals. Our findings suggest that facilitating HR practices for IT professionals will have little or no *direct* impact on actual firm productivity. However, we find that these practices have a positive moderating effect on the marginal productivity contributions of IT investment. In other words, we find that the effect of IT investment on actual firm productivity increases with the use of facilitating HR practices for IT professionals. This result shows that the business value of IT is inexorably linked to the rewards and opportunities offered to IT professionals—who have a pivotal role in the effective deployment of IT in organizations. Therefore, this result contributes to the literature on HR practices for IT professionals, by showing that HR practices for IT professionals have particular implications for firm performance. These results shed light upon potential inter-linkages between the business value of IT literature (Brynjolfsson and Hitt 2003; Brynjolfsson, Hitt and Yang 2002) and the literature on HR practices for IT professionals (Ang et al. 2002; Ferratt et al. 2005; Mithas and Krishnan 2007), which have thus far been studied separately.

Managerial Implications

Information-intensive knowledge work is particularly dependent upon a culture that fosters collaboration, autonomy, and flexible work structures, among other characteristics of facilitating HR. Our results suggest that, particularly in knowledge-intensive industries, HR practices designed to empower employees may have limited impact without adequate technology tools that enable collaboration, knowledge-sharing, and information access. Likewise, the cluster of facilitating IT practices will have little impact on productivity without adequate facilitating HR practices that empower employees with greater autonomy, flexibility, and an environment that fosters trust and makes employees feel valued. Based on our results, we argue that such facilitating HR practices not only encourage the use of facilitating IT by employees, but also help ensure that the use of these technologies is effective. Therefore, when seeking to improve productivity of knowledge-workers, we suggest that managers should synchronize the deployment of productivity-oriented IT with HR practices that create a work-environment conducive to the effective use IT. They should also examine the extent to which the firm's technology infrastructure and set of practices supports any HR-driven initiatives for worker productivity.

A look at the role of IT professionals enables us to consider in more precise terms how the interaction of IT and HR practices can affect a firm's productivity. We have found that certain innovative HR practices positively moderate the effect of IT investments on firm productivity. This suggests that firms are able to derive greater value from IT investments (which include hardware, software, and compensation to IT professionals) by implementing HR practices that empower IT professionals. Given what we know about the potential of IT professionals to act as drivers of organizational innovation (Bassellier and Benbasat 2004; Moore and Love 2005; Swanson 1994), managers should consider more seriously the rewards and opportunities provided to their IT employees in how such practices may be influencing the firm's ability to leverage value from IT investments.

Limitations and Suggestions for Future Research

We point to some limitations of our study and provide suggestions for future research. First, the system of HR practices that we have presented deal primarily with management practices that influence employees' work practices and behavior, such as information sharing, autonomy, and benefits. Future studies may consider other aspects of HR, such as employee sourcing, deployment, hiring and retention practices. Second, our study used a proxy of knowledge work using industry-level employee education profiles, and subsequently narrowed the scope of our focus to IT professionals. Future studies may use richer operationalization of knowledge work and compare the alignment of IT and HR practices for the types of knowledge work other than that of IT professionals. Third, it is important to consider how certain elements of corporate strategy, such as strategies of competition or innovation, shape firms' IT and HR practices. The differences in firms' HR and IT practices may reflect variations in corporate culture, values, structure, or strategy, and it is possible to extend our framework to account for this. Finally, researchers can explore other potential connections between HR practices for IT professionals and the business value of IT.

Conclusion

This paper develops and empirically validates a theory of alignment between IT and HR practices of firms. We examine the interaction between IT and HR practices for knowledge workers in their effects on firm performance. We contribute to the literature on firm productivity impacts of IT and HR alignment in two ways. First, we consider the use of specific IT practices, opening the black box of IT. We found that the use of facilitating IT practices positively moderates the effect of facilitating HR practices on firm productivity, in industries in which highly educated workers account for a large portion of labor. Second, we consider a specific type of knowledge worker-- IT professionals. Using quantitative economic measures of firm productivity, we find that facilitating HR practices have a positive moderating influence on the effect of IT investment on firm productivity.

The continued expansion of the services and technology sectors of the economy, as well as the digitization of business processes, has influenced the nature of work and the necessary skill sets (Mithas and Krishnan 2007; Mithas and Whitaker 2007; Rai and Sambamurthy 2006; Ramasubbu, Mithas and Krishnan 2007a; Ramasubbu et al. 2007b). Given that IT is transforming the nature of desirable employee skill sets, our study represents a step towards greater understanding of how of HR-IT alignment can be effective at leveraging the capabilities of workers in the knowledge economy.

Appendix

Dependent Variables

Perceived Increase of Productivity (PROD): This is a 5-point Likert scale indicating the respondent's perceived improvement in the organization's current level of productivity compared to the same time a year ago. From the Optimize survey.

Value Added (VA): This measure of productivity was used in Bresnahan et al. (2002), Brynjolfsson and Hitt (2003), and Brynjolfsson et al. (2002). This is computed as $VA = \text{Sales} - \text{Materials}$. Sales is the Sales (Net) as reported in Compustat item #29. Materials quantity is calculated as Total Expenses – Labor Expenses. Total Expenses are calculated as Sales (Compustat item #12) minus Operating Income Before Depreciation (Compustat item #13). The dependent variable was lagged by one year.

Independent Variables

Facilitating IT (FACIT): This is a six-item summative scale indicating the number of forms of facilitating IT work-practices listed by managers as among the most effective technology steps that have been made to raise worker productivity. These include the deployment of collaborative software tools such as Intranet and email, the deployment of knowledge management tools, the supporting of mobile access to business applications/data, the offering of self-service employee/recruitment intranet sites, the installation of instant messenger, and the allowance of more workers to access the Internet. These technologies or policies belong to this category because they facilitate

collaboration and communication among workers, or make data, knowledge, or information more accessible to workers. From the Optimize survey.

Facilitating HR Practices (FACHR): This is a six-item summative scale indicating the number of non-technology actions or policies that correspond with a facilitating HR system. These include such practices as fostering a team environment, boosting pay above the cost of living, implementing cross training of skills, adjusting business practices to support new technology, improving ergonomics for workers, and improving worker benefits with flex time, on-site daycare, or extended leaves. Many of these practices were mentioned explicitly in Ichniowski et al. (1997), and Milgrom and Roberts (1995). This class of workplace innovations fosters greater worker autonomy, teamwork and collaboration, investing in workers skills and knowledge, and other practices that motivate workers by making them feel more valued. From the Optimize survey.

Facilitating HR Practices for IT professionals (FACHRITP): This is a multi-item scale indicating the number of non-technology actions or policies for IT professionals that correspond with a facilitating HR system. These include such practices as providing opportunities for promotion, providing rewards and opportunities for electronically-based learning as well as other company-paid educational and training opportunities, encouraging innovation, providing performance based incentives such as cash or stock bonuses or stock options, opportunities for telecommuting, career path planning, recognition for good work, and increased responsibilities to keep work challenging. From IWeek 2003.

Knowledge Work Intensity (KW): We use the firm's industry-level education profile to proxy this variable (Becker and Chiswick 1966; Coff 1999). We developed this measure using two separate data sets from the Bureau of Labor Statistics: 1) The most recent (May 2005) Occupational Employment and Wage Estimates at the 3-digit NAICS industry level, which contains data on the proportion of wages accounted for by each BLS occupation in each industry, and 2) The most recent (2004) Occupational Employment and Job Opening/Worker Characteristics Data, which contains data on the educational attainment levels of employees in each BLS occupation. Using the "Educational and Training Classifications" guidelines presented in the handbook *BLS Occupational Projections and Training Data (2006-07)*, we grouped firms into one of 6 clusters (1 being lowest) depending on the percentage of employees having attained high school, some college education (including Associates degrees), or Bachelors degree. Based on this classification system, we separated the sample into two. The high knowledge-work firms are those in clusters 4 or above; for such firms, KW=1. Otherwise, KW=0.

IT Expenditure (IT): This represents the firm's worldwide IT budget in a single year, including capital and operating expenses for infrastructure such as telecommunications, networking, hardware, applications (maintenance and development and packaged), Internet-based costs, salaries and recruitment, IT services/outsourcing, and training. Respondents provided this figure in terms of percentage of revenue, which was then multiplied by annual sales to get the total value of IT Capital. Since we used 2003 figures only, we did not apply any deflators. From IWeek 2003.

Control Variables

Functional Areas in Measuring Worker Productivity: Dummy variables were used to indicate whether the organization tracks worker productivity in the areas on Manufacturing (*TrkMnfcturingWrk*), Services (*TrkServicesWrk*), IT (*TrkInfotechWrk*), knowledge work/analysis (*TrkKnowledgeWrk*), and other functional areas (*TrkOtherFuncArea*). Respondents could specify multiple functional areas. From Optimize magazine.

Firm Size (SIZE): This is a bracketed variable indicating firm size in terms of annual sales revenue where 1= \$7 million to under \$50 million, 2= \$50 million to \$99 million, 3= \$100 million to \$499 million, 4= \$500 million to \$999 million, 5= \$1 billion to under \$5 billion, 6 = \$5 billion and higher. From Optimize magazine.

Labor Expenses (L): Following Bresnahan et al.(2002), Brynjolfsson and Hitt (2003), Brynjolfsson et al. (2002), we used the Labor and Related Expenses as reported in Compustat (item #42) if it was available.

If Labor expenses was not reported in Compustat, we used the following method to determine industry weighted labor expenses: First, we used data from the Bureau of Labor Statistics (BLS) data to obtain the hourly cost of workers (including benefits) for ten sectors of the economy. We multiplied this by the number of employees in the firm (Compustat item #29), and an estimated number of work hours per year. As several of the firms in our sample are multi-industry conglomerates, we computed the firm's *weighted* industry average labor expense using the percentage of the firm's sales from each industry segment (using the Compustat Segments database):

Weighted Industry Average Labor Expense = $(Employees) \times \left(\sum_j \bar{L}_j P_j \right)$, where \bar{L}_j is the average labor expense for industry j and P_j is the portion of the firm's revenue in industry j.

Capital (K): We followed the procedure described in Bresnahan et al.(2002). We used the total value of physical assets, "Property, Plant, & Equipment (Total- Gross)", Compustat item #7, which was deflated using the implicit GDP fixed investment deflator, applied at the average age of capital. The average age of capital was calculated as the three year average of the ratio of total accumulated depreciation, "Property, Plant, & Equipment (Total- Net)," (Compustat item #8) over current depreciation, "Depreciation and Amortization," (Compustat item #14).

Industry controls: Following the procedures described in Bresnahan et al. (2002), we constructed dummy variables for each of the following industries: High Technology Manufacturing, Other Durable Manufacturing, Process Manufacturing, Trade, and Other Services, Conglomerates, Construction, Finance, Health Care, Non-durables Manufacturing, Professional Services, Transportation, and Utilities.

Industry-level IT Capital Intensity (ITCAPINTENS): Ratio of IT investment to total fixed asset investment; collected from the Bureau of Economic Analysis (BEA). IT investment is the total sum of investments in computers and peripheral equipment, software, and communications equipment, divided by the total of fixed assets. BEA has provided these figures at varying levels of aggregation across 2, 3 or 4 digit NAICS codes. We matched the focal firm's primary NAICS code industry classification to the most detailed NAICS classification provided by BEA.

Validating Measures of Facilitating HR and Facilitating IT

Principle components analysis (PCA) was used to validate measures of facilitating HR (FACHR, and FACHRITP) and facilitating IT (FACIT). Principle component loadings are provided in Table 5. All variables that comprise FACHR, FACIT, and FACHRITP load positively onto on the first principle component. Kaiser-Meyer-Olkin values of 0.73 for FACHR, 0.80 for FACIT, and 0.92 for FACHRITP indicate high levels of internal consistency for each of these measures. Therefore, we concluded that these items can be included in a single representative summative metric.

Item	FACHR	FACHRITP	Item	FACIT
Incentives	0.29	0.34	Internet access	0.34
Flexible working arrangements	0.42	0.34	Laptop	0.35
Training	0.40	0.32	Mobile access	0.32
Equity ownership	0.27	0.32	Collab. software	0.36
Teams	0.39		Collab. hardware	0.36
Ergonomics	0.25		Knowledge mgmt.	0.36
Adjust bus. practices	0.40		Self-serve intranet	0.30
Compensation	0.36		Instant messaging	0.31
Encourage Innovation		0.34	Telecommuting	0.28
Promotion		0.27		
E-Learning opportunities		0.34		
Career path planning		0.32		
Recognition		0.29		
Responsibilities		0.27		
<i>Kaiser-Meyer-Olkin Measure¹</i>	0.73	0.92		0.80

¹ The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy indicates the degree to which variables belong together by virtue of their correlations and partial correlations (Kaiser 1970). KMO values above 0.60 indicate that the variables are suitable for factoring.

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