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Distributed Knowledge and Creativity in the International Software Industry[1]

Abstract

- The growth of outsourcing of intellectual work has provoked a major debate in wealthy countries concerning the loss of jobs to developing countries. However, what is the limit to this distribution of work?
- We interviewed several software and client companies as well as conducted extended field research. The qualitative work was matched by a questionnaire.

Key Results

- These triangulated methods indicated a surprising convergence among co-located and distributed projects, indicating that firms have acquired a body of skills to manage intellectual work across distance and national boundaries. The efficacy of these practices is contingent on the importance of a heavy-weight manager to oversee the project. However, the more creativity was required, the more likely work would be co-located than dispersed.
- These results indicate that the managerial experience to support global outsourcing of intellectual labor is already advanced, while creativity remains more likely to be located in rich countries.

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Introduction

In the first part of the 19th century, Great Britain entertained an active debate regarding the dangers of the transmission of knowledge across borders. This debate led first to the enactment of laws that forbade the migration of skilled workers and that became a cause of grievance between England and the backward United States. In the later debates that eventually led to the repeal of these acts, other voices such as Andrew Ure noted that the success of the UK did not lie in its preservation, but its creation of knowledge (Ure 1835). England, and Birmingham more exactly, was to be the innovative leader of the world economy.

It is not coincidental that Charles Babbage, famed today as the inventor of the mechanical computer, should have proposed a division of mental labor (Babbage 1835). Since brains were scarce and expensive, it made sense to assign less skilled (including women and children) to low paying and less skilled jobs. The vertical division of mental labor concluded with the more intellectually capable directing work and the innovative process.

These two elements of the geography of innovation and the vertical division of mental labour have become the background knowledge of the modern world. Innovation is done in the Silicon Valley, Toulouse, Baden-Württemberg, Tokyo, and Seoul. This list suggests that the world has changed since Ure and Babbage, but it is still an unequal world, with a handful of largely western and a few Asian countries dominating the indices of innovation.

The explanation of this persistence is both simple and complicated. The simplicity is that innovation addresses the needs of advanced consumers located in richer countries. Since it is intensive in human capital, its location favors countries rich in educational resources. A smart person in less advantaged parts of the world either had not the luxury to be educated, or if schooled, could not easily participate in innovation. These observations are easily confirmed by migration flows of educated people from poor countries to rich countries, but until recent times, rarely in the reverse. Human capital migrated to be in proximity with physical capital.

The complicating aspect of this story is to ask why this situation should endure? One possibility is to posit a path dependence in which past investments have resulted in localized knowledge, much of it held tacitly as the background knowledge of how intellectual work is done. The design of semiconductors, or the combinatorial chemistry of biotechnology, consists of knowledge encoded in books and articles which are not nevertheless easily accessible. Participation in the networks of knowledge is vital in order to acquire the technological skills for innovation and valued intellectual work. For this reason, the little evidence regarding innovative regions that we have appears suggests that the job movement of skilled workers loyal to a region is critical to innovative success (Almeida/Kogut 1999). Perhaps in this regard, the British concern over the migration of skills was not entirely nonsensical.

These two explanations are not competitors, but complements. They raise the interesting question what would happen if the economics of space should be eliminated. Imagine that the transport of ideas, and products, should be of zero cost. Would regions still exist?

This hypothetical question has become a practical reality in the past decade, primarily in the software and information technology industries. The expansion of information technologies amplifies the division of mental labor among countries and regions. A long tradition in the economics of location explains the distribution of firm activities across space based on the economics of weight and transportation. However, when ideas can be encoded in electronic bytes, considerations of weight and transportation vanish. Due to similar quality training available in many – though not all – countries, (e.g. US, India, Ireland, Israel, Germany, France), human capital for mental work exists in many locations throughout the world. Consequently, costs and productivity should, by economic logic, drive location decisions.

Software is an exemplar case of study for the study of the meaning of geography in the absence of the standard spatial costs. Because intellectual work uses ideas as inputs and outputs to the production process, and since the transport of these ideas is not bounded by weight, any two points in the world appear as co-located from the point of view of economic transportation. This economic implication lies at the heart of the current debate in many rich countries regarding the outsourcing of skilled jobs to India and other Asian countries.

Our aim in this study is to analyze the international division of mental labor by identifying the limits and potentials of the spatial distribution and coordination of software design and programming. We begin with a simple hypothesis that software projects requiring a greater creative content are more likely to be located in the United States for the period under study. From this perspective, we examine how the digitalization of task content, the increased sophistication of communication technology, and spatial coordination are rapidly changing parameters to the decisions of companies in the software industry. Our study provides an analytical window into a rapidly moving frontier that has implications far broader than those currently impacting the software industry. Similar dramatic changes affect all activities that can be encoded in bytes and transmitted over distances.

Software design and production are activities common to many industries. As the content of work continues to shift from material processing to knowledge creation, the demand for software increases, no matter if the company is in the computer industry, in insurance, or in the creative arts. The digitalization of content, the ability to provide services remotely, and the replacement of mechanical by electronic design are all driven by the writing and maintenance of software code. To the extent that such activities as film making and editing, back office processing of data and text, education, or service support (to name a few examples) can be digitally-encoded and transmitted, the software industry is representative of a far-reaching revolution in the nature of work.

To avoid confusion, it is useful to define at the outset the central terms used throughout this paper. Onshore activities refers to development activities carried by US firms in the US. Offshore activities refers to the software development work done by US firms in their own Indian offshore development centers. Outsourcing refers to the software development done in India, by Indian for US companies. Hybrid projects are those partly done in the US and partly done in India. Co-location designates the physical proximity of two or more activities.

We rely upon two types of data: interviews and administered questionnaires. The interviews were conducted in Bangalore, Singapore, and in the United States with American, Indian, and Singaporean managers involved in software development. These interviews revealed somewhat distinct perceptions of managers who operate in different environments. Managers who operate mainly in the US perceived the impact of the digital revolution as a force to be recognized but one that would not dramatically affect the location and organization of work. However, the executives who are closely involved in offshore operations emphasized the implications posed by the new technologies for the compression of time and space.

There is good reason to believe that the demand for software will only be met by a rapid globalization of work. In India, this young industry (the first software companies were established in the mid-1980's) has been growing at annual rates of 50–55% over the past ten years. According to Nasscom[2], the Indian software and services exports grew from $ 6.5 Billion in 1998 to $ 9.8 Billion in 2003. Out of this volume 67.7% of software exports are to the US. It is also significant that over time, the offshore activities grew much faster than the services provided by Indian companies at their clients' site.

The very fluidity of the environment makes the findings of our study even more valuable. By capturing the factors that impact this dynamism, we can understand the motivations and the limits of this growing phenomenon. Clearly, a complex dynamic is here at work. The technology makes possible increasingly richer interactions across distances, a process that reinforces firms' propensity to locate abroad in their search for economic rents and for talents. In their turn, the demands of coordination among distant locations require even more sophisticated communication links, and this need pushes the technologies even further. We recognize that the phenomenon of offshore location is largely driven by this dynamic.

At the same time, this dynamic is also influenced by the need to collocate activities requiring creativity. As Analee Saxenian (1996) has shown in her study of the Silicon Valley, the region's success is supported by a culture of free communication among engineers. The information technology revolution poses, therefore, a fundamental question that lies at the center of our inquiry: does the observed division of labor reflect the limits to the virtual coordination of creative work?

We address this question by investigating the spatial distribution of software work among various locations worldwide and the influences of three factors on the location decision: shared context of the strategic mission, task and product design, and communication. These dimensions are empirically grounded in an ethnographic study of dispersed software development teams (Metiu 2001).

In summary, the increasing digitalization of work makes intellectual tasks such as software writing virtually co-located. However, we hypothesize that the decision to locate intellectual activities also hinges on factors representing the limits imposed by human and machine languages, as well as on the shared context of human interaction. Because the knowledge needed for some tasks is not easily communicated among distant parties, we find that particular projects are retained at locations even where factor costs are higher.

The International Software Industry

To understand our research design, it is instructive to consider first the traditional models of software design and the importance of the software industry for the study of the growing distribution of mental labour. The software industry's digital, and at the same time modular and systemic character, makes it a perfect setting for the study of the international division of intellectual labor. During the last several decades the US have largely dominated this industry; however, in the last ten years, we have witnessed the rise of software writing centers in several regions of the globe. The most prominent centers are located in India, Ireland and Israel. While many US firms outsource parts of software development and maintenance to Irish or Indian firms, other multinationals have set up development centers that operate on the basis of long-term agreements on prices for time and materials.

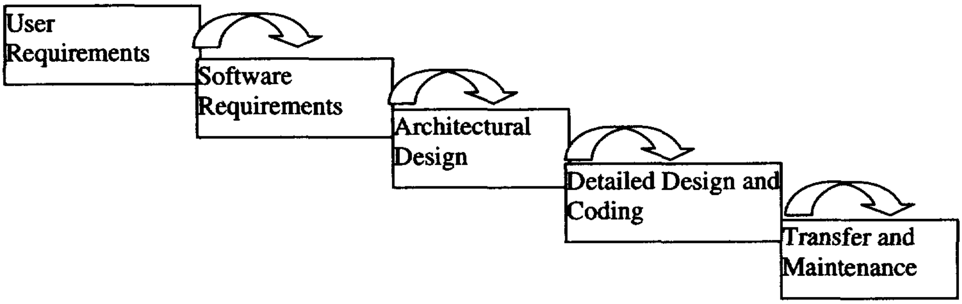
The issue of internal development versus outsourcing in software development has been the focus of modeling in recent research (Whang 1992, Richmond/Seidmann/Whinston 1992). Wang, Barron, and Seidmann (1997) argue that such models are limited by their neglect of the informational disparities inherent in software contracting. They show that the developers' skill and business knowledge are not invariant with different sources or providers because outsourcers tend to specialize in a particular industry, where they develop industry specific know-how. Consequently, Wang et al. (1997) take into account explicitly the necessity of communication between parties. Their model and numerical experiments show that an internal developer has a substantial advantage over an outsourcer. Two recent empirical studies support this claim. Nelson et al. (1996) examine 186 projects from five firms and find that 75% were done internally. Also, the case studies of Lacity et al. (1996) lead to the recommendation that organizations develop internally projects that require familiarity with existing business processes.

The tension between creative and well-understood tasks is present in studies of the software industry in general. Cusumano (1991) documented the emergence, first in the United States, of the concept of a software "factory" designed to rationalize the process of software production, as well as the adoption and implementation of this concept in the Japanese companies Hitachi, Toshiba, NEC, and Fujitsu. In the attempt to make the development of software more cost-effective, firms proceeded to standardize software tools and environments and to re-use code in different projects. This approach culminated in an attempt to rationalize the entire cycle of software production, installation, and maintenance through the establishment of factory-like procedures and processes. At issue, however, is whether the factory concept increases quality and productivity only at the cost of flexibility, creativity, and the adequate meeting of specific customer needs. Cusumano's view is that software factories were not the answer to new and complex systems because the processes involved in this type of projects are only imperfectly understood.

Ultimately, these studies aimed at improving project performance. However, very few of them attempted to assess this outcome via large scale surveys. An earlier quantitative study by Cusumano and Kemerer (1990) compares the performance of 24 US and 16 Japanese software development projects. The analyses indicate that Japanese software projects perform at least as well as US counterparts in basic measures of productivity, quality, and reuse of software code. Similarly, in one of the few surveys of software development projects, Kraut and Streeter (1995) found that their coordination will be difficult when specifications are incomplete, when the knowledge needed is not documented and therefore not easily available. They also found that coordination was impeded as project size and complexity increase, and that the maintenance of informal communication networks was an important determinant of project success.

The most modest of the strategies involved in distributed activities is to exploit simply the cost advantage by assigning routine tasks to offshore sites. These tasks might be the maintenance of legacy systems, developing highly specialized but routine modules, or completing entirely the detailed design work of a software project. Modularity is easy to achieve, communication requirements are low, and there is little concern over shared context. As shown in Figure 1 for the traditional waterfall model, module tasks are separable and, thus, easy to locate in different places.

Figure 1. The Waterfall Model Minimizes the Need for Coordination and Communication because it Sees the Process of Software Development as a Cascade of Phases, the Output of One Being the Input to the Next



The waterfall model is a stylized view of programming that is often rejected by software engineers. In a research workshop held with software designers from many firms and countries, a manager of a highly innovative project characterized the waterfall model as possible for only routine work. Creative work, he insisted, demanded a chaotic model in which the design of the downstream steps simultaneously caused alterations in the upstream architecture. This model of development was highly interactive and dynamic.

The waterfall model has served as a principal point of reference for the design of international software projects. Interviews with software engineers, as discussed below, indicate that the waterfall model had been the operating guide for the assignment of software programming to contractors located in India. These contractors provided so-called "Offshore Development Centers" or ODCs. The larger contractors maintained several ODCs as separate "silos", that is, under strict confidentiality not to share information with the other centers. In some cases, these ODCs functioned as virtual units to the contracting American firm. These centers have also been called "bodyshop" centers to denote that their value-added has been traditionally the writing of code to meet the requirements and architecture determined already by the onshore contracting customer. It is not surprising that a waterfall model appears to fit well the "bodyshop" services provided traditionally by offshore contractors.

In trying to understand the decision to locate programming offshore, it is critical to consider two boundaries: the national boundary (i.e. the decision to locate "offshore") and the firm boundary (i.e. the decision to contract or not). Both of these boundaries posed difficulties for coordination which are often addressed through innovative efforts to integrate the "offshore" and "outsourced" contractor within the firm. An indication of the efforts to integrate was the investment by a large American financial services firm in communication systems, including the assignment of internal phone numbers to the Indian programmers. As a result, an American employee composed only the last numbers of an internal exchange (such as, x4329) to call the Indian contractors located in India.

There is, in effect, an important element of caution regarding the potential for selection bias in the research design. We witness only the projects that have already been made, that is, the projects deemed feasible to outsourcing and/or contracting. Once the decision is made, many of the critical dimensions that determined location may appear similar among onshore and offshore work. However, some dimensions may represent features that cannot be easily resolved by investments in communication or organization. As we will argue and show below, the most important dimension that differentiates onshore from offshore work is the saliency of creativity. It is this dimension that has been argued, as we noted above, to be the less amenable to the implementation of a waterfall type of production process.

The Spatial Distribution of Work

Software is the writing of symbolic code to achieve particular functions to be executed by computers and electronic devices. Since the capital investment consists largely of computers, software, and communication infrastructure, its production is heavily biased towards mental labour relative to traditional capital-intensive industries. As wage rates and the availability of brains vary by geography, there are strong economic incentives to source software from distributed locations.

We wish to understand the motives for, and the limits of, the spatial distribution of work tasks in a distributed intelligence environment in reference to the co-location decision. The variables of interest are a) location of software development activities (on shore or offshore) and b) project dimensions. In addition to the dimensions of coordination and communication, property rights issues may impact location decisions for certain software tasks (e.g. source code), as well as labor cost differentials between various locations. For example, at the time of the first data collection, an entry level software programmer recruited by one of India's top domestic software companies expected to earn about $ 500 a month; his American counterpart earned approximately $ 3,000 (*Financial Times* December 2, 1998).

Any model of the geography of production points to a few central determinants of location: the factor costs of production, transportation costs, location of demand. The expansive literature on economic development stresses the importance of "backward and forward linkages" to other industries. Though these linkages have been difficult to conceptualize and analyze, work by Becker and Murphy (1992) provides the interesting insight that the division of labor is influenced by the general degree of knowledge available in a system. In their work, production is characterized by the constraint that all elements to a task must be accomplished such that the minimally efficient task determines global efficiency. Much of software writing has, in fact, this characteristic, whereby the product cannot be shipped until all modules are completed and integrated.

This analytical frame captures the explanation offered by Babbage that we discussed earlier, namely, that differences in productivity and wages among classes of workers give rise to a "mental" division of labor (Babbage 1835). This division of labor is, consequently, a vertical hierarchy, in which less complex work is assigned to less productive and less expensive labor. The more skilled workers are reserved for more complex work, where their higher wages are justified by their higher productivity at mental labor. It is important to underline here that Becker and Murphy imply that productivity differences among workers can be explained by differences in the degree of general knowledge available to them. This point is especially significant in light that highly educated workers in an offshore site may be less productive due to inefficiencies in the local economic environment.

Leaving aside coordination costs, the economics of software would suggest a tremendous advantage for offshore production. Factor costs are remarkably less expensive in, say, India. Though energy provision is highly problematic, small firms internalize such costs by purchasing an assemblage of batteries for outages, while larger firms install small generator facilities. Costs are still estimated to be substantially below sites in developed countries. Transportation costs are negligible, since the product is transmitted by satellites. Satellite communication also avoids the costs and uncertainties of depending upon local networks and roads. Human capital is rapidly deepening, since countries like India and Ireland (where the wage costs are substantially higher) have developed efficient institutions of technical education.

If factor and transportation costs indicate the absolute advantage of offshore location, what then are the forces that determine the decision to locate software in a given site? A critical determinant in the decision to locate a project must be the costs of coordination. We focus upon three elements that influence the costs of coordination over distance: the dimensions of the task, the limits to communication by various media, and the importance of shared context.

Dimensions of Task: Tacitness and Hidden Knowledge of Modules

Work tasks display a great diversity in terms of the underlying knowledge bases, as well as the type of effort required for their successful completion. Our paper gives due attention to the finding that knowledge transfers are not abstract transactions between information-transmitters and information-receivers, but exchanges in which the identity of the two parties is crucial for success. As Brown and Duguid (2001) have argued, significant amount of innovation takes place in the informal communities of practice existing in each firm. These informal groups linking individuals within and across formal organizational boundaries are the loci for innovation, because individuals and groups create knowledge as they interact with the things and activities of the social and physical world (Brown/Duguid 2001). This line of thinking clarifies the reason why knowledge cannot be simply transferred among various firms.

This conception of firms has been explored by organizational scholars interested in the tacit aspects of work processes that will make technology difficult to imitate and transfer within and across organizations. Expanding upon Rogers (1980) and Winter (1987), Kogut and Zander (1992) propose that the firm is a repository not only of information, but also of social knowledge or know-how, which is largely tacit hence difficult to communicate and imitate. That firms act as social communities for the creation and communication of knowledge is apparent in their statistical results that found that the transfer of innovations among Swedish firms was significantly affected by the extent to which the knowledge can be articulated in documents and software, as well as by the extent to which workers can be trained in schools or on the job (Kogut/Zander 1993; Zander/ Kogut 1995).

The challenge of knowledge articulation is also apparent in the work of Szulanski (1996). Like von Hippel (1994), he refers to the 'stickiness' of knowledge as the factor impeding the transfer of best practices within the same firm. Sticky knowledge is causally ambiguous and unproven. Causal ambiguity captures the extent to which the precise reasons for success or failure in replicating a capability in a new setting cannot be determined even *ex post*. In another study of knowledge transfer within a large multinational enterprise, Hansen (1999) shows that the transmission of knowledge that is noncodified and dependent is difficult to communicate across divisions, and its transfer necessitates frequent and close ties between a firm's divisions.

Clearly, the limitations imposed by the complex, dependent, and tacit character of knowledge can be offset, in part, by modularity. Modules permit the use of "hidden knowledge". Software engineers responsible for one module only need to know the interface with other modules, not their internal code. Some competencies can be joined with modular design as long as each task results in a module that can be assembled independent of knowing the competence of each team. Also, in the process of designing a modular product, some of the tacit knowledge about components and their interfaces becomes explicit. However, some tasks cannot be modularized; or, if a certain degree of modularization can be achieved, the task still requires large overlaps between various knowledge bases. In such cases, rich and intense communication is needed for the sharing of both tacit and explicit competencies. In the words of Frederick Brooks, "since software construction is inherently a systems effort – an exercise in complex interrelationships – communication effort is great, and it quickly dominates the decrease in individual task time brought about by partitioning" (1975, p. 19).

However, the emphasis on the sharing and transfer of knowledge obscures an important aspect of work design: transfer occurs subsequent to, or concomitant with, innovation and creativity. A main dimension that emerged in our study is creativity. Radical creativity can be defined as revolutionary changes that depart from existing practices and solutions (Dewar/Dutton 1986). Traditionally however, creativity was conceptualized as more adaptive adjustments to established practices. For example, Perrow (1967, 1970) introduced the concept of routineness – defined as a function of the extent to which the task contains variety and is analyzable – in order to arrive at a definition of creativity. In this view, creative tasks involve either tasks that cannot be broken down into small and well-defined components, or those that require variation in the needed knowledge bases.

This concept of creative tasks is also supported by psychologists, who argue that "novelty can arise from either or both of two sources: novelty of the component mental operations, and novelty of the content of the problems" (Gardner/Sternberg 1994, p. 40).

We would like to stress this alternative conception of innovation that emphasizes the importance of interactivity in the generation of new knowledge. As we discussed above, the emergence of knowledge in communities of practice is one of the reasons for the tacitness of the produced knowledge. Similarly, the work of von Hippel (1988) stresses the role of interactivity between firms and their users. His work shows how, contrary to common-sense views, many new innovative ideas come from the end users.

Communication Media

The difficulty of transmitting some kinds of knowledge required for software production over digital media is an important element to our understanding of why there are lasting differences between the tasks performed in different regions. There is a vast literature, not entirely consistent, regarding the relationship of media and communication across distance. Table 1 reviews the vast literature on the sophistication of new communication media such as the computer and the video, and their effects on perceived complexity, dependence, and even tacitness. As a result of this range of work, it is not practical to review all of these many studies. We consequently highlight a few that are particularly relevant to our findings.

A frequent claim is the argument that ambiguity and non-routineness (or innovativeness) bias communication toward face-to-face or voice media. Daft and Lengel, among others, argue that particularly in the case of ambiguous tasks,

Table 1. A Review of Empirical Research on the Effects of Communication Media

Issue	Studies	Face-to-Face Communication (FTF)	Computer-Mediated-Communication (CMC)
WORK TASKS			
Decision making			
Time to reach decision	Dubrovsky et al. (1991), Siegel et al. (1986)		four to ten times longer to reach a decision than FTF groups
	Arunachalam and Dilla (1992), Daly (1993), George et al. (1990)		longer time than FTF
	Reid et al. (1997)		much longer than FTF
Types of decisions	McGuire et al. (1986), Siegel et al. (1986), Weisband (1992)		riskier decisions, and more choice shift
Quality of decisions	Hiltz et al. (1986), Hollingshead (1996 a)	no difference	no difference
	Hedlund et al. (1998)	much better decision accuracy	
Satisfaction with decision	Reid et al. (1997)	better	
	Gallupe et al. (1988)	more satisfaction with the decision process	
	Gallupe et al. (1988)	more confidence in their decisions	
	Gallupe and McKeen (1990)		significantly less satisfied with decision process than FTF groups
Idea-generation			
number of unique ideas	Straus and McGrath (1994)	higher number of unique ideas than CMC	worse
	Daly (1993)	same number of correct solutions	same
	Gallupe et al. (1992)		more nonredundant ideas than FTF groups in 4- and 6-member groups, but not in the 2-member groups
	Gallupe et al. 1988 (task was crisis management)		more alternatives were generated than in FTF
	George et al. (1990) (task is idea generation/ intellective)	same number of unique alternatives	

Table 1. A Review of Empirical Research on the Effects of Communication Media (continued)

Issue	Studies	Face-to-Face Communication (FTF)	Computer-Mediated-Communication (CMC)
Quality of ideas	Straus and McGrath (1994)	same	same
	Gallupe et al. (1992)		better ideas than FTF groups in 4- and 6-member groups, but not in the 2-member groups
	Gallupe et al. (1988)		better quality decisions were generated than in FTF
	George et al. (1990)	same quality of decisions	
Judgement task: achieve goal consensus	Straus and McGrath (1994), Reid et al. (1997)	better	worse
	McLeod and Liker (1992)	better on the decision-making task, which required a response to in-basket correspondence	
Intellective task (pick correct solution)	Straus and McGrath (1994)	same	same
	Hollingshead (1996b)	better on intellective task (when given instructions to rank-order decision alternatives)	
	McLeod and Liker (1992)		better than FTF groups; the task also required consensus in terms of the proper sequence of activities
Number of errors	Daly, B. (1993), task is intellective	lower number of errors	higher
Creativity	Cummings et al. (1995), task was essay generation	At the beginning, FTF-generated essays were more complex	Over time, essays generated via CMC were more complex
Negotiation			
	Hollingshead et al. (1993)	better on negotiation and intellective tasks than CMC groups	
Transfer-pricing negotiation	Arunachalam and Dilla (1992)	higher performance	lower outcomes, and distributed resources more unequally, and deviated from the integrative agreement, and maintained more inaccurate perceptions of the interaction

Table 1. A Review of Empirical Research on the Effects of Communication Media (continued)

Issue	Studies	Face-to-Face Communication (FTF)	Computer-Mediated-Communication (CMC)
INTERACTION PROCESS			
Volume and frequency of communication	Hiltz et al. (1986)	more	less
	McGuire et al. (1987) (task is investment decision)	more	less
	Siegel et al. (1986)	more	less
Content of communication	Hiltz et al. (1986)		larger % of task-oriented messages
	McLeod and Liker (1992)	longer responses; greater awareness of underlying problems	more task-oriented behavior
	Weisband (1992)		more task-irrelevant remarks
	Dubrovsky et al. (1991), Weisband (1992)		more diverse opinions or decision recommendations
	Smith and Vanecek (1990) (complex intellective task; participants were volunteers from professional organizations and several corporations)	FTF groups shared more of the important info needed for finding the correct solution, derived more correct reasons for eliminating wrong alternatives, and perceived more progress than CMC groups	
	Hollingshead (1996a)		information more readily accessible
	Weisband (1992)		more implicit preferences and explicit proposals; more social pressure remarks
Discussion Style	Reid et al. (1997)	more factual	more normative
	Dubrovsky et al. (1991) Siegel et al. (1986) Weisband (1992)		less inhibition, more personal expression (including profanity and insults)
	Sproull and Kiesler (1986)		more uninhibited and nonconforming behavior through electronic mail

Table 1. A Review of Empirical Research on the Effects of Communication Media (continued)

Issue	Studies	Face-to-Face Communication (FTF)	Computer-Mediated-Communication (CMC)
	Straus (1991)		same degree of negative interpersonal communication as FTF; higher proportion of positive interpersonal communication than FTF
	Arunachalam and Dilla (1992)		more competitive flaming behavior; more tendency to reach coalitional agreements
	Kiesler et al. (1985) (task is dyads getting to know each other)		subjects evaluated each other less positively and were more uninhibited in their comments
Social effects			
Equalization of participation	McGuire et al. (1987), Siegel et al. (1986), Weisband (1992), Daly (1993), George et al. (1990)		equalization of team members' participation (because of anonymity)
	Hollingshead (1996a)		information suppression effect, which really accounts for the equalization of participation
	McLeod and Liker (1992) (tasks are intellective ranking and decision-making)	no difference	no difference
Status differences	Dubrovsky et al. (1991)		high status members less likely to dominate the discussion
	Hiltz et al. (1986)	dominant member more likely to emerge	
	Weisband et al. (1995)	high status members participated more and had greater influence than low status members	high status members participated more and had greater influence than low status members
	Spears and Lea (1994)		the technology may be used by high status individuals to exert greater power and influence over low status individuals

Table 1. A Review of Empirical Research on the Effects of Communication Media (continued)

Issue	Studies	Face-to-Face Communication (FTF)	Computer-Mediated-Communication (CMC)
Group development			
degree of cohesiveness	Chidambaram et al. (1991) (task is decision making w/o 'correct' answers)	manual (i.e., paper-and-pencil) groups did better initially (first 2 weeks)	CMC groups became more cohesive in the 3rd and 4th sessions
conflict management within the group	Chidambaram et al. (1991)	manual (= paper-and-pencil) groups did better initially (first 2 weeks)	CMC groups managed conflict better in the 3rd and 4th weeks
	Gallupe et al. (1988)	less conflict in group discussions than CMC groups	
Affect			
Anxiety level	Daly (1993)		higher (reported) level of anxiety and nervousness during experiment
	Gallupe et al. (1992)		less evaluation apprehension than FTF groups

communication requirements are much higher than for routine tasks (Daft/Lengel 1986). Also, Galbraith (1977) shows that task routineness influences the groups' communication structure because it determines the information processing requirements of the group.

The social psychology literature has addressed some of the issues related to the types of tasks for which co-location and face-to-face interactions are important. This literature holds that face-to-face communication is needed for substantial consensus decisions, and when the equivocality of the task is high. McKenney, Zack, and Doherty's (1992) study of the communication patterns in a programming team concludes that electronic mail and face-to-face are complementary media: while email provides efficiency in well-defined contexts, face-to-face has the ability to build a shared understanding and definition of the task. Coordination at a distance is costly if not impossible because the medium of communication (mainly the computer) misses a whole host of non-verbal cues that influence message reception and understanding. In the same vein, Nohria and Eccles (1992) argue that face-to-face communication has three main advantages over electronic communication: the existence of a shared context among participants, its richness which encompasses the full bandwidth of physical senses and psychoemotional reactions, and its capacity for interruption, repair, feedback and learning.

More detailed studies of the limitations of computer-mediated communication have been discussed by authors such as McGrath and Hollingshead (1994). They observe that this medium often alters communication times, as well as the sequence and synchrony of messages. At the same time, it increases ambiguity because the sender cannot be confident that failure of any given member to reply to a given message in a timely fashion reflects that member's deliberate choice (1994, p. 21). Groups using computer-mediated communication try to supplement the lack of nonverbal cues by using "emoticons" as well as a) longer and more complex syntax; b) jargon, argot, and other shared nonstandard language that relies on culturally shared connotative meanings; c) punctuation and format conventions; and d) redundancy (McGrath and Hollingshead 1994, p. 19). However, all these supplements can only provide a low-quality substitute for what humans routinely do with nonverbal cues.

Our project paid attention to several mechanisms used to coordinate effort in distributed teams. Our interviews sought out managers who specifically fulfill the role of liaison between teams situated at large distances and who provide such coordination. We also attended the planned and unplanned meetings that bring together people in routine or exceptional circumstances (Metiu 2001). We believe that tracing the reasons for face-to-face meetings over the course of the projects will further shed light on the relationship between certain types of tasks and the need for physical proximity.

Shared Context

The rise of new technologies such as the video and especially computer-mediated communication has led to a vast literature that has examined the virtues of various communication media on work performance. As seen from Table 1, this literature is rife with interesting yet contradictory findings. For example, some studies find that face-to-face communication generates a higher number of unique ideas; however, other studies find that computer-mediated communication generates more nonredundant ideas; yet other studies find no difference between the two types of communication media in terms of the number and quality of ideas generated. We believe that the lack of robustness of these results is due to the spuriousness caused by the lack of attention to contextual factors. As most of this research has been primarily experimental, it has neglected the degree of impact that a shared context has on people's interactions.

Some tasks require close interactions with customers, and this is a common explanation given by many of the Indian firms to explain why they are less innovative. Our study recognizes the importance of close interaction with the customer when the requirements are unclear, or are changing during the course of the project. However, it is also important that the information to be gleaned from customers cannot be easily parametized. When the software developers are unfamiliar with the functionality of the end product of their work, the communication of the product's features may be difficult.

The impact of a shared context is particularly important in the case of creative and highly tacit tasks. Work in the area of creativity has always been confronted by the difficulty that creativity is difficult to organize as a task and thus cannot be easily parametized along the dimensions of complexity and non-modularity.

Creativity, therefore, is linked to a host of "unobservables" such as creativity climate or labor supply characteristics. Saxenian's (1996) study of the Silicon Valley is a good example of an attempt to identify the factors that have led to the region's continued inventiveness. Apart from the role played by venture capital firms and major universities in the Bay Area, the region's rich creativity is largely tied to a certain culture of free communication among engineers, to a sustained desire and effort to invent something new. Saxenian's work, as well as Almeida and Kogut's (1999) study of the networks of relationships linking engineers in the semiconductor industry, highlight the role of spatial proximity in sustaining an intense atmosphere of creativity.

Also, tasks with a high tacit component may require physical co-location. As competences are often non-articulable, they can only be transmitted through common participation in an activity. Lave and Wenger (1991) show that learning some crafts requires not simply a transmission of abstract concepts, but also effective co-participation in an activity. Such concrete actions, performed together, give access to and refine a wealth of nonverbal communication cues that can enhance understanding and speed execution. More importantly, the knowledge being created in face to face interactions entails often the assessment of others' degree of involvement in the common activity. It is this part of the knowledge produced during face to face interactions that is largely non-articulable.

We hypothesize that tasks that are non-modular, complex, creative, tacit, and require a shared context with the customer, as well as a high degree of coordination and customer interaction, will be co-located, and will not be located overseas in spite of the cost advantages of such locations.

Methodology

We explored the issues delineated above via a questionnaire. The research design and survey instrument were created after we conducted extensive interviews with executives and engineers in US, Indian and Irish firms.

The main analyses in this study employ the project as their unit of analysis. For example, creative and non-modular tasks are hypothesized to be co-located. In contradistinction, creative and modular projects could be dispersed. However, we allow for the possibility that various stages in the development process may differ according to dimensions such as creativity or tacitness, and that such differences may account for the division of labor among countries in terms of software development. Consequently, our design will permit us to check whether the fault lines between onshore and offshore work lie along the project development stages (requirements, design, coding). This approach is warranted on the basis of our interviews, some of which indicated that stages of project development are best done in a co-located mode.

We will compare projects done in a collocated fashion (in onshore locations) with dispersed projects. Because our study is exploratory and affected by selection bias as discussed above, the statistical results need to be interpreted with caution. Generalizing the results to the location decisions of small, or new firms should be done with care, because we have chosen projects done by large, established US firms. When the subjects are highly heterogeneous, the results for any subgroup are likely to be imprecise because of unobserved variation. This imprecision may lead to a lack of confidence in the validity of the results; in turn, such imprecision precludes generalization. In other words, we factored out potential contamination of the statistical results by selective design.

Apart from location, the other dependent variable of interest is project performance. Our sampling technique reflects that many projects are for internal use rather than for external customers. We assess the performance of software projects by using several measures such as quality, time to completion, cost, and creativity. Hence we are able to avoid the selection bias problem generated by the use of commercial success as the sole performance measure. The managers and engineers to whom we talked explained the variety of motives for which firms decide to do offshore development. One of the main reasons is to achieve 24-hour development, especially critical for products in very competitive markets.

The questionnaire also provided part of the raw data for the study of coordination mechanisms between distantly located teams. Our interviews have revealed that many unplanned meetings occur at critical junctures in the projects, and often it is deemed that only a face-to-face encounter (often lasting several days) can solve the problem satisfactorily.

Data

We have obtained a sample of 40 projects from several firms. Ten of these projects were collocated (i.e., they were accomplished in only one location) and 30 were accomplished across at least two different sites or locations. Out of the collocated projects, 7 were done in India and 3 in Singapore. The 30 dispersed

Table 2. Project Characteristics

	Collocated	Dispersed	Total
Total projects:	10	30	40
– out of which ongoing	5	21	26
Average project length (in months)	10	22	19
Internal projects	4	5	9
External client projects	10	21	31

projects were done over locations in the US, India, Singapore, China, Japan, Finland, Switzerland, and the UK. Out of the 30 dispersed projects, only 2 were done in more than 2 locations. Table 2 provides a description of our sample along several dimensions of interest.

The length of the projects ranged widely, from 1 month to 60 months. However, the respondents were competent to evaluate the projects given that the average project, at the time of the survey administration, had been operating for 10 months in the case of collocaded, and 22 months in the case of dispersed projects. Both collocated and dispersed projects involve system software, middleware, and application customisations.

The respondents were project managers, out of which 80% had a background in engineering, 5% in management, and 11% some other background. When asked to choose their current professional identity, 23% said engineering, and 77% responded they identified with management. This pattern of response reflects the typical career path in software engineering where after several years in technical positions, people take on management responsibilities.

Results

Several results merit attention. First, the striking result of our study is that once a firm decides to use a remote location, the properties of the projects, whether collocated or dispersed, are about the same. A comparison of the collocated and dispersed projects reveals that they do not differ significantly along the dimensions of coordination, modularity, and tacitness.

Creative Work

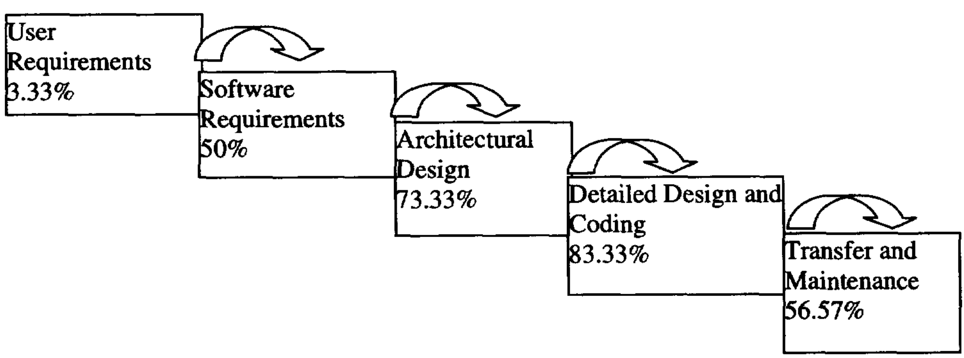
Given our findings about the many dimensions on which collocated and dispersed projects are done, the question becomes: what does differentiate the two types of projects? The interesting dimension of differentiation turns out to be creativity. In the software industry, creativity remains hard to source from far away. Projects that are supposed to find innovative solutions tend to be accomplished in a dispersed rather than in a collocated fashion (t-test significant at the 0.05 level)[3].

Further analyses advance an explanation for the findings, an explanation related to the need for proximity to customers. Our survey asked respondents to list which activities (collecting user requirements, architecture, coding etc.) were done at each location. An examination of the activities performed in various locations for the dispersed projects reveals a telling picture.

Of the 30 dispersed projects, all but one did the user requirements phase in locations other than India or Singapore. Also, only on 15 projects was the software requirements phase done in India or Singapore (or China). On 22 projects the architecture phase was done in India or Singapore or China. On 25 projects the coding was done in India or Singapore or China. The transfer and maintenance phase of 17 involved India or Singapore or China; naturally, this phase also involved the developed world locations in the case of 21 projects. Figure 2 portrays the trend above by displaying the proportion of the dispersed projects' activities done in offshore locations (India, Singapore, China).

Figure 2 illustrates quite powerfully the main findings of our study. The first is that creativity is an important challenge in distributed work. The need to create products for sophisticated customers located in developed countries does not pose technical problems to remote developers; clearly, they can often (50% of the time in our sample) translate the user requirements into software requirements, and even do the architectural design of products in over 70% of cases in our setting. However, what is hard to outsource at a distance is the knowledge of customer needs, particularly when those needs are not familiar to workers in the developing world. Of course, one of the implications of our findings is that if it weren't for this constraint, much more work will get sent to offshore locations.

Figure 2. Proportion of the Share of Work Done Offshore for Each Stage of a Software Development Project



The lack of familiarity of workers in offshore sites with the requirements of most sophisticated clients is a challenge to offshore sites and managers. To the question 'this product was a common item in the project members' lives', the answers from dispered projects were much lower then those from collocated projects (t-test significant at the 0.05 level).

Even more surprisingly, and related to the above, our respondents rated dispersed projects higher on the dimension of importance of the product to the firm's future stream of products (t-test significant at the 0.05 level). The progress made by offshore sites in securing work on strategically important projects has been quick and explains the rapid growth of offshore activities in several countries. The finding that dispersed projects involved software that was considered to be important to the firm's future stream of products documents the increasing competency of offshore sites in providing high-quality services to their clients. It also therefore explains the sustained growth of offshore centers such as Bangalore.

Process Management

To the practicing manager, the challenges posed by tacit knowledge are addressed by process tools. We asked first did problems occur. Secondly, we asked how such problems were resolved.

In examining the way collocated and dispersed projects are managed, we found no significant differences in the two types of projects in terms of the frequency or the type of problems encountered. 80% of the collocated and 87% of the dispersed projects report having encountered technical problems. Also, 20% of the collocated and 40% of the dispersed projects report having encountered people-related problems. While the dispersed projects seem to experience higher proportions of people-related problems, these differences are not significant.

For the resolution of these problems, the dispersed projects relied more on the activities of a heavyweight manager (t-test significant at the 0.05 level). The results illustrate the importance of a manager who, in dispersed projects, conveys information across sites and solves problems as they come along. Heavyweight managers have been found to be crucial to innovative capabilities, such as in automobiles (Clark/Fujimoto 1991) and pharmaceuticals (Cockburn/Henderson 1998). This finding shows that dispersed projects may be similar in most regards to onshore projects because of the organizational capability of the contracting firm to manage such projects through heavyweight managers.

Communication

Our data does not reveal a difference in the amount of face-to-face interactions in the two types of teams. In fact, the two types of teams seem to use face-to-face and email communications in similar proportions. The difference comes with teleconferencing and videoconferencing, of which distributed teams make more use (but the differences only approach significance). Our findings enable us to suggest that the emphasis on face-to-face interactivity may have been over-rated.

The bias towards a priori over-rating the importance of face-to-face communication arises out of the tendency to take collocated settings, and the face-to-face type of interactivity that is specific to these settings, as the norm. Indeed, managers of collocated projects rate the importance of face-to-face interactions for project success more highly than managers of dispersed projects (means of 5.67 vs. 5.27). Clearly, both categories of managers rate quite highly the importance of face-to-face interactions. However, managers with experience in dispersed environments have learned efficient ways of getting around the constraint of face-to-face communication.

Factor Analyses

In an exploratory study, it is of interest to look for patterns in the data that are not expected *a priori.* A common technique for such exploration is factor analysis. Since our sample is not large, we report simply the loadings with the caution that these results are suggestive.

Table 3. Factor Analyses

	Formalization	Iterativeness	Novelty
Ease of monitoring	**0.49914***	−0.43210	−0.30398
Requirements were clear	**0.40612**	−0.45481	0.39184
Cultural differences not a problem	**0.54121**	0.31483	−0.65689
Location not affected by culture	**0.58168**	0.45715	0.45343
Easy to monitor progress	**0.75379**	0.38343	−0.20316
Modularity	**0.50548**	0.36003	0.07591
Easy to work independently	**0.73823**	−0.09056	0.24679
Degree of documentation	**0.72506**	0.17305	0.07861
Newcomers learn quickly	**0.52130**	−0.11115	0.40160
GAP analysis easy	0.33658	−0.14831	0.17162
Technical solutions were innovative	0.29939	0.13343	−0.13016
Iterativeness	0.04322	**0.41304**	0.09652
User interfaces	0.24591	**0.40468**	−0.23592
Product was familiar to workers	0.11211	**0.64284**	−0.13104
Work was codified	0.04016	**0.35713**	0.15818
Change affects other projects	0.21749	0.47699	**0.58908**
Product solved a novel problem	−0.20469	0.39287	**0.51133**
Reused components	0.06565	0.05815	**0.68880**
Contact of personnel was important	−0.11079	0.34148	**0.39583**
Documentation was an important output	−0.16230	0.12759	0.34972
Process synchronization was important	0.04361	−0.25668	0.28870

* factors >0.35 are highlighted.

The questionnaire was designed to look at project characteristics along the dimensions of tacitness and modularity, communication, and shared context,. These items were analyzed using principal components and varimax rotation. A three-factor structure was revealed, as seen in Table 3.

The first group of variables loads on project characteristics related to modularity, work independence, clarity of requirements, ease of monitoring progress and of bringing newcomers up to speed, amount of documentation. We call this underlying factor 'project formalization' as a measure of the routinization of knowledge. A second group of factors pertains to need for process synchronization, the amount of contact among personnel, the need to solve a new problem, the amount of changes in requirements, the familiarity of personnel with the product. A third group has to do with the familiarity with the product, with the need to design user interfaces, with the fact that the work was not coded in manuals, and with the iterativeness of the project (as opposed to waterfall). This group of factors has to do basically with the creativity that needs proximity to the customer.

Discussion

This exploratory study shows that creativity is the main obstacle to the dispersion of mental work across space. While outsourcing of software activities grows at a fast pace, the closeness to customers who provide ideas and inputs for innovativeness remains important. This result is consistent with a body of literature that has emphasized the interactive nature of innovation.

It is also consistent with the results of our interviews, in which offshore managers repeatedly mentioned the acquisition of domain knowledge as their most significant challenge. Software development managers distinguish between two types of knowledge needed for project accomplishment. Technical knowledge involves expertise with hardware and software, mastery of programming languages, and understanding the documentation. The managers interviewed did not see technical knowledge as posing problems for the accomplishment of work in offshore sites. Domain knowledge however, is a challenge. It involves understanding the product, the requirements, and learning the application domain (for ex., healthcare systems, or telecommunications). These types of knowledge were seen as major hurdles for offshore sites. As the manager of an Indian subsidiary of a US firm said "My main challenge is understanding how the product impacts the customer. Knowing the big picture, how my work is impacting the product is key."

In other words, the obstacle to distributed work was not the tacitness of technical knowledge. Engineers felt this type of information was amenable to communication over distance. Rather, the primary obstacle was the communication of the larger picture, how a piece of programming is important to the project and, ultimately, to the client.

Interestingly, we found similarities in terms of the process of coordination in the two types of projects. Both encountered comparable levels of technical and people-related problems. Respondents reported non-significant differences for the importance of face-to-face interactions. This result is surprising, as the general consensus among managers and management scholars has been that collocated groups are efficient at coordination because they can talk out problems together, keep all the details of the task in focus, and organize work (Nohria/Eccles 1992, Kameda et al. 1992).

We advance two alternative explanations for this result. The first points to the expertise at managing across distance that managers and developers involved in dispersed projects have developed. Furthermore, the companies that provide outsourcing services have developed process management capabilities that carefully store project-related knowledge and, when appropriate, transferred it to new projects. Of course, part of the attention to process is due to the need to reassure customers who may not trust from the beginning the outsourcing team's competence and motivation. The second explanation is that our sample contains only projects that had been deemed appropriate for outsourcing. Since our sample did not contain projects that were done completely in the developed world, we cannot discriminate between these two explanations. Further work that will include a variety of projects (completely outsourced, hybrid, and completely done in the developed world) will be able to address this issue more directly.

While surprising, the finding that managers of dispersed projects have identified and are successfully practicing efficient ways to coordinate activities in the absence of face-to-face communication helps to explain our result of the similarity in project dimensions and coordination. The major challenge for dispersed projects, therefore, is one of closeness to customers who are the source of requirements and of product ideas.

The larger implication of our finding is that the division of labor among various regions is changing. This observation has obvious implications for new software centers outside of India. Initially, the developed world did not only the user requirements stage, but also the software requirements and particularly the architecture stage. As long as that kind of division of labor persisted, engineers in the developed countries did not feel threatened by their counterparts in outsourcing centers. However, as our research has uncovered, that division of labor has been changing rapidly over the past few years. The recent heating of the debates over outsourcing and over H1B visas[4] in the US are an echo of this phenomenon.

Conclusions

The current debate over out-sourcing in the United States and Europe reflects a concern over the loss of skilled jobs to developing countries. It is easy to respond to these criticisms by an implicit appeal to general equilibrium in which increased earnings of workers in poor countries lead to an increase in goods produced by rich countries. Indeed, the striking element of a visit to a Bangalore firm is the presence of state-of-the-art computers and software bought from western countries.

Whatever the general equilibrium argument, the rapid rise of new regions in poor countries producing the infrastructural software supporting information technologies speaks to certain arbitrage gains. As we have noted in the context of open source software (Kogut/Metiu 2001), one of the most wasteful features of the global economy is the failure to incorporate fully 2/3 of the world's brains in the production of new ideas. The expansion of communication infrastructures, and the digitalization of work and product, permits an arbitrage of this potential that has not ever been possible.

Because this arbitrage potential is so large, it is to be expected that growth rates of software production can be remarkably high during this period in the few regions in poor countries able to educate a skilled workforce. This explosion obscures the continued presence of severe obstacles to the distribution of intellectual labour globally. Our study has especially noted the obstacles for software products that require innovative work.

The experience of managing distributed work is still immature, but managerial processes are already surprisingly efficient. However, a key element in the global management of intellectual work is the so-called "heavy-weight manager". It is a page from a science fiction script that even in the most technologically advanced industrial frontiers, human intervention and management remains salient.

Endnotes

1 We would like to thank INSEAD for the funding of this research and Professor Uwe Fischer for the opportunity to contribute to this collection in honor of Professor Klaus Macharzina.
2 India's National Association of Software and Service Companies.
3 All t-tests are one-tailed.
4 H-1B visas are nonimmigrant visa issued by the US government to individuals who seek temporary entry in a specialty occupation as a professional. Many of the visa holders are software developers from countries such as India. For the fiscal year 2004, beginning October 2003, there is a maximum of 65,000 H-1B visas issued.

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