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The effect of information technology and knowledge management capability on R&D process performance

Huimin Ma and Yibing Peng
School of Management, Huazhong University of Science & Technology, Wuhan, People's Republic of China, and
Yongjiang Shi
Institute for Manufacturing, University of Cambridge, Cambridge, UK

Abstract

Purpose – The main purpose of this paper is to develop the theoretical links and empirically examine the association between IT and R&D performance, and their study is to answer management's questions: how should IT resources be organized and managed to enhance the process performance?

Design/methodology/approach – The approach is consistent with the process perspective to the question of IT business value, but this approach is extend. A basic premise of this paper is that the knowledge management (KM) capability could be a critical mediator between IT capability and process performance.

Findings – The results indicate that an organization's KM capability is dependent on IT capabilities, and variation in business process performance is explained by KM capability.

Research limitations/implications – On the one hand, control variables were not included in this study. In fact, firm size might influence process performance. On another hand, the empirical analysis was conducted in the context of one specific process in the manufacturing industry; thus, the generalizability of the results may be limited.

Practical implications – The results indicated that IT managers have to clearly understand the strategic thrust of the organization and institute mechanisms to ensure that IT capabilities are channeled toward the areas important to the organization.

Originality/value – This study contributes to the IT literature by introducing KM capability as a critical mediator between IT capabilities and business process performance, this study improves our understanding of the true business value of IT.

Keywords Business policy, Business performance, Communication technologies, Knowledge management, Research and development

Paper type Research paper

In recent years, a growing number of Chinese manufacturing plants have poured money into IT projects (e.g. ERP, CRM, CAD, PDM) in pursuit of greater performance and export potential. The impact of this technology, however, is not that obvious. Business and IT executives continue to struggle with a host of complex issues involved in determining payoffs from IT investments, especially when considering recently emerging economies. For instance, past empirical research examining the link between IT and firm performance has concentrated mainly on developed countries, resulting in a dearth of information on developing countries.

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In this paper, our approach is consistent with the process perspective to the question of IT business value, suggesting that the enterprise level impact of IT can be measured only through their intermediate (i.e. process) level contributions (Tallon *et al.*, 2000). The paper's basic premise is that KM capability (Tanriverdi, 2005) could be a critical mediator between IT capability and process performance.

The purpose of this paper is to develop the theoretical links and empirically examine the association between IT and process performance. To accomplish this objective, it was first necessary to choose an industry within which to concentrate our focus. The manufacturing industry was chosen for three reasons. Firstly, the manufacturing industry has been among the largest IT investors. Second, in the highly competitive manufacturing industry, R&D is widely seen as being strategically important in China. Finally, there is a high level of variance in effective IT implementation, resulting in a growing number of firms failing to gain a satisfactory process performance.

IT and business process performance: a critical review

Why and how could IT investment impact on process or firm performance? Recent researchers propose that KM capability could be a critical mediator between IT and process or firm performance (Tanriverdi, 2005). Traditionally, most research in strategic IT has focused on the ability of IT to add economic value to a firm either by reducing a firm's costs or by differentiating its products and services. A principal argument in this line of reasoning is that the competitive use of IT has the potential to provide sustainability and competitive advantage (Kettinger *et al.*, 1994; Clemons and Row, 1991). As knowledge is often the basis for the effective use of a firm's resources, a new line of IT-based systems must be introduced to support organization knowledge management systems. KMS have been defined as a line of systems which target professional and managerial activities by focusing on creating, gathering, organizing and disseminating an organization's "knowledge" as opposed to "information" or "data".

Information system researchers posit that IT enhances the KM capabilities of organizations (Alavi and Leidner, 2001; Gold *et al.*, 2001; Schultze and Leidner, 2002). Furthermore, organizational theorists and strategists suggest that KM capabilities provide competitive advantage and increase process or firm performance. Adopting this view, Ray *et al.* (2005) presents an empirical study that examines the extent to which IT impacts on customer service processes in the insurance industry, and found that there is no positive relationship between the flexibility of the IT infrastructure and relative process performance, and the KM capability affects customer service process performance and moderates the impacts of explicit IT resource.

Despite widespread belief that IT enables KM and KM improves process or firm performance, systematic empirical investigations of these relationships are scarce. Reviews of the IT literature do not identify any study that establishes a link from IT to KM capability, or from KM capability to process performance (Schultze and Leidner, 2002). In this paper, therefore, we seek to address this gap by theorizing about KM capability, IT capabilities, IT resources and process performance. Adopting an approach similar to the process perspective, we examine how IT resources, IT capabilities, and KM capabilities affect process performance, whilst also developing the theoretical explanations underlying these causal links.

Research model and hypotheses

We propose a research model that inter-relates six constructs: R&D Process performance, KM capabilities, IT capabilities, IT resources, complementary human resources, and relationship resources (Figure 1). Drawing from the notion of resource complementarities, we posit that R&D process's ability to create performance using IT is a function of its ability to use IT to develop and enhance KM capabilities. We also posit that this capability is dependent on having strong functional capabilities within the IT department, which in turn is influenced by the nature of human, information technological, and relationship resources possessed by the IT department. In this model (Figure 1), we focused on information technology investment in R&D process, such as CAD/CAPP/PDM applications, which has been widely implemented in China.

KM capabilities

KM refers to identifying and leveraging the collective knowledge in an organization to help the organization compete (von Krogh, 1998). Among a variety of knowledge resources, Tanriverdi and Venkatraman (2005) identify product, customer, and managerial knowledge as the most-strategic knowledge resources in firms. KM capability is defined as the firm's ability to create, transfer, integrate, and leverage related knowledge in firms.

A common application of KMs is the creation of knowledge networks. For examples, Ford found that just by sharing knowledge, the development time for cars was reduced from 36 to 24 months, and through knowledge sharing with dealers, the delivery delay reduced from 50 to 15 days. The key contributions of KM capability include: improved ability to innovate, improved coordination of efforts, and rapid commercialization of new products (Gold *et al.*, 2001). KM capability enables the firm to exploit related R&D and operations knowledge and to reduce the overall R&D and operations costs of firm (Markides and Williamson, 1994). Thus:

H1. There is a positive relationship between KM capability and R&D process performance.

IT capability

IT capabilities are the routines within the IT department that enable it to deliver IT services to the organization. It can create an infrastructure and environment that

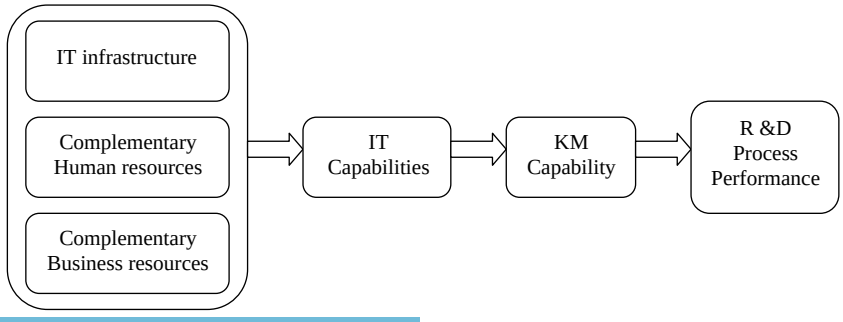

Figure 1.
Research model

contribute to organizational KM by actualizing, supporting, augmenting, and reinforcing knowledge processes at a deep level through enhancing their underlying dynamics, scope, timing, and overall synergy. KM, by drawing on various IT tools and capabilities, can play a variety of roles in support of organizational KM processes. It is important to note that KM, by drawing on various and flexible IT capabilities, can lead to various forms of KM support, extending beyond the traditional storage and retrieval of coded knowledge. Organizations that do not have strong IT capabilities might find it difficult to both initiate and sustain innovative projects targeted at enhancing KM capabilities, and provide reliable IT services that might be critical for smooth KM operations. Thus:

H2. There is a positive relationship between IT capabilities and KM capabilities.

IT resources

Resources are the raw materials in the development of capabilities. This relationship is implicit in the definition of capabilities as an organization's ability to deploy resources (Amit and Schoemaker, 1993). The causal relationship between resources and capabilities is more formally stated by the dynamic capabilities perspective, where asset positions are posited to affect capability development (Teece *et al.*, 1997). Three broad categories of resources have been identified in the IT literature – human, technological, and relationship resources (Powell and Dent-Micallef, 1997). Consistent with prior IT research, which has emphasized the importance of intangible resources, we focus on these three resources. Specifically, our research model includes complementary human resources, IT infrastructure, and complementary relationship resources.

Human resources

The critical dimension of human IT resources include:

- Technical IT skills, such as programming, systems analysis and design, and competencies in emerging technologies.
- IT human resources specificity, which pertains to the extent to which IT personnel have firm-specific knowledge such as an understanding of the culture and routines of the culture and routines of the organization (Ravichandran and Lertwongsatien, 2000).

Firm with strong human IT resources are able to:

- Integrate the IT and KM more effectively.
- Conceive of and develop reliable and cost effective applications that support the business needs of the firm faster than competition.
- Communicate and work with R&D unites efficiently.
- Anticipate future business needs of the firm and innovate valuable new product features before one's competitors (Bharadwaj, 2000).

IT activities are generally considered knowledge-intensive and require specific technical skills (Teo and King, 1997). Moreover, appropriate business and interpersonal skills are needed to effectively deliver IT services to end-users (King *et al.*, 1989; Teo and King, 1997).

Thus, it is reasonable to argue that organizations with highly skilled IT personnel are better positioned to develop strong functional capabilities than those that do not. In addition to technical IT skills, firm-specific knowledge is critical in developing functional capabilities (Ravichandran and Lertwongsatien, 2000), because capabilities are essentially reflected in organizational routines (Nelson and Cooprider, 1996). Deep understanding of the organization's culture and norms is necessary to develop routines that fit the organizational context in which IT activities have to be carried out. Thus, it can be expected that firm-specific knowledge would be critical in the development of appropriate function capabilities. Thus:

H3. There is a positive relationship between complementary human resources and IT capabilities.

IT infrastructure

IT infrastructure is defined as a shared set of capital resources that provide the foundation on which specific IT applications are built (Broadbent *et al.*, 1999; Duncan, 1995). A flexible IT infrastructure can support a wide variety of technologies that can be easily diffused into the overall technological platform, to distribute any type of information-data, text, voice, images, and video-to anywhere inside of an organization (Gibson, 1993). A flexible IT infrastructure is also able to support the design, development, and implementation of a heterogeneity of business application. Reusable data and application asset can speed up application delivery by reducing the need for new development and facilitating integration with legacy systems. Moreover, a flexible IT infrastructure allows easy integration of new technologies with existing platforms, thereby allowing the IT unit to deliver cutting edge technology capabilities quickly and cost effectively. Thus:

H4. There is a positive relationship between IT infrastructure and IT capabilities.

Relationship resources

Relationship resource refers to a mutual respect and trusting rapport established over time between the IT function and the business (Ross *et al.*, 1996) that enables IT specialists and users to work together more effectively. When the R&D process units and the IT department develop mutual understanding and tighter relationships, the firm's ability to enhance existing IT-dependent strategic initiatives, as well as deploy new ones, increase. An investigation of high-performing IT functions in eight companies revealed that the enduring trait was a strong relationship between business and information systems professionals, often stemming from mutual respect and ongoing relationships developed over time (Chan, 2002).

Rockart and Short (1989) argued that an IT department's ability to deliver its services is dependent on an effective partnership between IT and line managers. In order for IT to deliver value to the firm, IT and line managers must develop an appreciation and understanding of each other's environment (Harris and Katz, 1989), which has been to found necessary for IT to deliver value (Ravichandran and Rai, 2000). Complementary business resources are a potential source of competitive advantage. Partner, customer, and IT-business relationships are important business resources that take time to build and can contribute to the process performance.

Moreover, business resources can be difficult to copy, valuable, and heterogeneous. Thus:

H5. There is a positive relationship between complement business resources and IT capabilities.

Research methodology

Data and sample

To test the conceptual model in Figure 1 and the associated hypotheses proposed above, we designed a questionnaire and conducted a survey. Our research focused on the manufacturing industry, which has been an early participant in information technology in China. Our subjects were managers and R&D engineers of manufacturing firms. We surveyed 187 manufacturing firms and interviewed their IT and R&D departments' employment. The pilot data were analyzed using several measures of internal consistency:

- Cronbach's α;
- item-to-total correlation; and
- item-to-item correlation.

The results of the various analyses were used as the criteria for eliminating six poor performing items. Subjects responded on likert type scales which ranged from 1 (strongly disagree) to 5 (strongly agree). Finally, subjects were asked background questions. The data was analyzed using SPSS 13.0.

Among the 187 companies investigated, there were 22 companies that were less than five years old, accounting for 11.8 percent of the sample. Sixty-eight companies (or 36.4 percent of the sample) were more than five but less than ten years old. Fifty-two companies (27.8 percent) were between 11 and 20 years old. The remaining 45 companies (24.1 percent) were more than 20 years old.

Of the 187 companies investigated, there were 17 companies (or 9.2 percent of the total sample) whose staff exceeded 5,000. Sixty-two companies (28.9 percent) had staff between 1,000 and 5,000, while 60 companies (31.6 percent) had staff between 500 and 1,000. The remaining 48 companies (30.3 percent) had staff consisting of less than 500 people.

Among the 187 companies investigated, there are 43 companies (or 23 percent of the total sample) whose total sales in 2005 were less than \$50, 000,000. Sixty-eight companies (36.4 percent) had sales of between \$50,000,000 and \$100, 000,000 during 2005. In 2005, fifty-eight companies (31.0 percent) had sales between \$100, 000,000 and \$500, 000,000, while the remaining 18 companies (9.6 percent) had sales exceeding \$500, 000,000.

Of the 187 people interviewed, there were 30 (or 16.0 percent of the total sample), senior managers 66 (35.3 percent) were mechanical engineers, 48 (25.7 percent) were IT technicians, and 43 (23.0 percent) were middle managers.

Operationalization of constructs and instrument validation

The development of the measurement model included several successive stages of theoretical modeling, statistical testing, and refinements. Measurement items were developed on the basis of a comprehensive review of the literature as well as expert opinion.

We then tested for constructs using confirmatory factor analysis (CFA). Based on the CFA assessment, the measurement model was further refined and then fitted again. Constructs and their associated indicators in the measurement model are discussed below.

Table I provides our conceptual definitions of the various constructs. We used four of the complementary business resource items that Zhuang and Albert (2006) did. The items we used to measure complementary human resources were from Dent-Micallef's study (1997). The IT resources and IT capability items used in our study were from Ravichandran and Lertwongsatien's study (2000). The items measuring IT capability were derived from Leonard-Barton (1992). The KM capability variables we used were analogous to Tanriverdi's KM capability variables (2005). Finally, we created the R&D process performance items. The reliability of each variable in the instrument was estimated.

To empirically assess the model theorized about above, we conducted a CFA using AMOS 6.0.We chose the algorithm of maximum likelihood estimation, which has been shown to be robust to departures from normality assumptions. We assessed construct reliability, convergent validity, and discriminant validity. Reliability refers to the extent to which a variable or set of variables is consistent in what it is intended to measure.

Complementary human resources □(Zhuang, Y.L. and Albert, L.L)□	
1	Our IT staff has very good technology knowledge in IT
2	Our IT staff understands R&D process very well
3	Our top executive have shown that IT is important to the company
4	We have very little formal bureaucracy in our company
Complementary business resources □(Dent-Micallef)□	
1	Conflicts between IT department and R&D department are rare and few in our organization
2	We seldom have Conflicts with our IT vendors and services providers
3	Conflicts with our IT vendors and service providers are resolved through discussions and not through litigation
4	Critical information and knowledge that affect IT projects are shared freely between R&D department and IT department
5	We get timely information from our vendors about unexpected problems
IT resources □(T. Ravichandran and Chalermsak Lertwongsatien)□	
1	The integration of information system is excellent
2	The speed of our network infrastructure adequately meets our current business needs
3	The technology infrastructure needed for current business operations is present and in place today
IT capability □(T. Ravichandran and Chalermsak Lertwongsatien)□	
1	IT planning is an ongoing process in our organization; planning is not a once-a-year activity
2	R&D department's participation in the IT planning process is very high
3	We have a formalized methodology for information system planning
4	Backup procedures are strictly enforced in our data center
KM capability □(Tanriverdi)□	
1	Creating R&D, marketing, managerial skills and knowledge
2	Transferring product, customer and managerial knowledge
3	Integrating relevant product, customer and managerial knowledge
4	Change product, customer and managerial knowledge
Process performance	
1	Cost of product manufacture is lower than before
2	Product quality is improved
3	Product manufacture cycle is shorter than before
4	We have more product innovation

Table I.
Measurement scales

These measures had composite reliability above the generally accepted level of 0.7, and had SMC above 0.50. Convergent validity refers to the extent to which two or more measures of one construct are consistent, and can be assessed by average variance extracted. All these measures had reliabilities above the generally accepted level of 0.5. Discriminant validity refers to the degree to which measures of different concepts are distinct in the model and can be evaluated by the correlations between the measures of different constructs. If two constructs are distinct, the measures of one construct should not be too highly correlated with those of another. The correlations between the constructs are lower than 0.85, so we can conclude that these constructs have discriminant validity.

Empirical analysis

Structure equation modeling is usually analyzed and interpreted in two stages. First, the measurement model is assessed and refined, followed by the evaluation of the structural model. A CFA was first applied to the independent variables. AMOS was used to determine whether IT infrastructure, complementary human resources, and complementary business resources were indeed three distinct constructs. AMOS provides a robust statistic that compensates for potential non-normality. The pairwise χ^2 difference and confidence interval tests provided evidence that the three resources were different. Next, a CFA was used to determine if all factors within each resource belonged together. Each of the three resources was assessed for goodness of fit, convergent validity, and discriminant validity. For IT infrastructure, the validation process resulted in the dropping of one item. For the other resources, no changes were necessary.

Further analyses supported the convergent and discriminant validity and reliability of the measurement model. The results is met the recommended thresholds. According to analyses above, we can conclude that our measurement model satisfies the various reliability and validity criteria. Thus, constructs developed by the present measurement model are robust and can be used to test the conceptual model and the associated hypotheses proposed earlier.

Standardized paths and various model-fit indices are shown in Table II The ratio of χ^2 to the degree of freedom (χ^2/df), also known as the discrepancy function, is a standard method of assessing model fit. A value between zero and three implies a good model fit and provides no evidence of overfitting. Our model had a discrepancy function value of 2.055, indicating a good model fit. In addition, we examined six incremental fit indices: NFI, GFI, AGFI, RMR, and CFI – and one parsimonious fit

Hypothesis (direction)	Path			Path coefficients	*t*-value
H1(+)	IT infrastructure	→	IT capability	0.401**	4.406
H2(+)	Complement human resources	→	IT capability	0.307**	2.419
H3(+)	Complement business resources	→	IT capability	0.349*	2.322
H4(+)	IT capability	→	KM capability	0.316**	4.673
H5(+)	KM capability	→	R&D process performance	0.291**	3.338

Notes: *$p < 0.1$; **$p < 0.05$

Table II.
Results of hypotheses testing

index – RMSEA. The incremental fit indices are all above the conventional cut off of 0.9, indicating an excellent model fit compared to a baseline model. Our model also has an acceptable RMSEA of 0.0784.

The results in Table II indicate that all path coefficients were statistically significant, complementary human resources (0.307, $p \leq 0.05$), IT resources (0.401; $p \leq 0.05$), and complementary business resources (0.349; $p \leq 0.1$) positively affect IT capabilities. IT capabilities (0.316; $p \leq 0.05$) significantly affect KM capability, which in turn, has a positive relationship with R&D process performance (0.291; $p \leq 0.05$). Thus, all hypotheses are supported.

Discussion

Organizations spend millions of dollars on IT to improve business performance. However, empirical studies examining the contribution of IT investments to firm performance show mixed result (Ray *et al.*, 2005). Researchers have called for the study of intermediate organizational variables (e.g. process-orientation, KM management) and the development of theoretical frameworks that facilitate such studies (Sambamurthy *et al.*, 2003). Our approach, synthesizing rich traditions from process-orientation, the resource-based theory and KM management, represents one step in that direction.

To understand special IT value (i.e. its impact on process performance) and how it enhances process performance, we have empirically tested five hypotheses using our approach. We posited and found that variation in firm's R&D process performance is explained by KM capability. We also posited and found that an organization's KM capability is dependents on IT functional capabilities, which in turn is dependent on the human resources, technology and relationship resources of the IT department.

The results provide empirical support for the notion that KM is a critical organizational capability through which IT influences process performance. Indeed, IT has the potential to improve R&D process performance (e.g. the efficiency and effectiveness of processes in an absolute sense). However, that IT is economically valuable does not necessarily mean that IT will improve the performance of a firm's processes relative to competing firms. Independent IT resources and capabilities did not affect R&D process performance directly. Both IT capability and KM capability are systems of complements. Achieving IT capability and KM capability simultaneously is very difficult. Our findings about the causal relationships between IT capabilities and KM capability and those between IT resources and IT capabilities highlight the path and time dependencies involved in using specific IT to pursue specific process performance. The results provide empirical support for the notion that specific IT has the potential to improve specific process performance when its capabilities are channeled to develop distinctive KM capabilities. Using IT to improve activities that are integral to KM capabilities results in resource bundles that are cannot be easily imitated by competitors because of isolating mechanisms such as causal ambiguity and resource connectedness.

This study contributes to the IT literature by introducing KM capability as a critical mediator between IT capabilities and process performance, it goes beyond the singular focus on IT investments and empirically examines the differential effects of IT resources, IT capabilities and KM capabilities on relative process performance. Although there is conceptual work in the IT literature on how and which IT resources are most likely to

affect performance, and empirical work examining the relationship between broad characterizations of IT capability and firm performance (Barua *et al.*, 2004; Bharadwaj, 2000), there is the first study to examine the impact of specific IT resources and capabilities on R&D process performance. The empirical findings are largely consistent with resource-based theory, process-orientation and KM perspective expectations, and this study improves our understanding of the true business value of IT.

Conclusions

Managerial implications

KM capability is an important intermediate organization mechanism through which the benefits of IT resources and capabilities are converted into R&D process performance. While managers acknowledge the strategic value of IT, they tend to view IT activities as commodity services, and target these activities when cutting costs. Our findings that strong IT capabilities enable organizations to improve KM capability, then in pursuit of R&D process performance.

The results indicated that IT managers have to clearly understand the strategic thrust of the organization and institute mechanisms to ensure that IT capabilities are channeled toward the areas important to the organization. Among other things, this requires close interactions with business managers. Co-opting business leaders need to play an active role in IT deployment decisions.

Our findings also demonstrate that resource endowments affect capability development, suggesting that IT managers have to develop effective resource acquisition strategies in order to maintain a valuable asset base comprised of personnel, technology, and relationships to support IT initiatives. Co-opting key vendors as partners and adopting sound vendor management practices are also critical in developing close vendor partnerships. IT managers have to recognize that all three types of resources are equally important and ensure a balanced approach to the acquisition and renewal of IT resources.

Limitations and future research

This study has the following limitations: on one hand we did not include control variables in this study. In fact, firm size might influence R&D process performance. On another hand, the empirical analysis was conducted in the context of one specific process in the manufacturing industry; thus, the generalizability of the results may be limited. The study raises a number of other important questions as well for future research. First, how is it that some firms are able to develop KM capability, while other firms are apparently unable to develop this capability? Additional research is needed to explore how KM capability can be developed and nurtured. Second, this study has examined KM capability between IT and the R&D process. Do IT units that have high level KM capability with one process, such as R&D process, tend to also have high level KM capability with other processes (e.g. manufacturing, customer service, and so forth)? All of these questions deserve additional attention. In addition, we also believe that role IT in organizational KM ought to receive considerable scholarly attention and become a focal point of inquiry.

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About the authors

Huimin Ma is the Associate Professor in the Department of Information Management, School of Management, Huazhong University of Science & Technology. Additionally he is also the Vice director of the Electronic Business Center of HUST in 2004. His major research field is the application of information technology in corporation, especially the application of Electronic Business.

Yibing Peng is a doctoral student in information systems at the Graduate School of Management, Huazhong University of Science & Technology, China. His research include the economic and organizational impacts of IT, electronic commerce, and the alignment of IT and business strategy.

Yongjiang Shi, University Lecturer and Research Director in the Centre for International Manufacturing. He joined the Cambridge manufacturing research group in 1994 and gained the PhD at Cambridge for work on International Manufacturing Network Configurations and has taken a leading role in the conceptualisation and delivery of the Centre's research programme. Before that, he taught Production and Operations Management at the School of Economics and Management in Tsinghua University, Beijing, PRC. The research areas of Yongjiang Shi are "Global Manufacturing Virtual Network", "Developing International Manufacturing Capability" and "Multination Corporations" "Strategies in China".