Journal of Technology Management & Innovation

Received October 13, 2007 / Accepted December 14, 2007

TECHNOLOGICAL INNOVATION FOR CHINA'S LOGISTICS INDUSTRY

Chieh-Yu Lin
Associate Professor, Department of International Business
Chang Jung Christian University
396, Sec.1, Chang Jung Rd., Kway Jen, Tainan, 71101, Taiwan
Tel: 886-6-2785123 ext 2154
Fax: 886-6-2785662
E-Mail: jylin@mail.cjcu.edu.tw

Yi-Hui Ho
Assistant Professor, Department of International Business
Chang Jung Christian University
396, Sec.1, Chang Jung Rd., Kway Jen, Tainan, 71101, Taiwan
Tel: 886-6-2785123 ext 2158
Fax: 886-6-2785662
E-Mail: vicky@mail.cjcu.edu.tw

Abstract

China's logistics industry has started to pay attention to adopt more efficient logistics technologies to provide better services for their customers. This paper employes the questionnaire survey to study the factors influencing the adoption of technological innovations by logistics service providers in China as well as the influences of technological innovation on supply chain performance. Technological innovations are categorized into data acquisition technologies, information technologies, warehousing technologies, and transportation technologies. The results show that the adoption of technological innovations is significantly influenced by technological, organizational and environmental factors, and adopting innovative technologies will increase supply chain performance for the logistics industry in China.

Keywords: Technological innovation, technology adoption, supply chain performance, logistics industry, determinants of innovation, China

Introduction

More than two decades of economic reform and transition to market economy has brought China unprecedented economic growth. With the fast growth in China's economy and China's accession into the World Trade Organization (WTO), the demand for logistics services has been growing significantly in China, and the logistics industry in China is set to take off. The total logistics value has grown by 29.9 per cent year-on-year (China Distribution & Trading, 2005). New modern facilities such as logistics parks, distribution centers and warehouses are being built at a record setting pace. Many logistics companies have invested extensively in information and logistics technologies. As China continues to develop into a global manufacturing factory, China's logistics industry will play an important role in the global supply chain. One key to effective supply chain is to make the logistics function more efficiently (Bowersox *et al*., 2002). The globalization of supply chain has prompted many firms to develop logistics as a part of their corporate

strategy (McGinnis and Kohn, 2002). To deliver products quickly to customers, many companies seek to outsource their logistics activities to logistics service providers. This reflects the trend of using logistics service providers to satisfy increasing need for logistics services (Lieb and Miller, 2002).

To fully satisfy the diversifying requirements of customers, many logistics service providers improve their service efficiency by continuous adoption of information or automation technologies (Mason-Jones and Towill, 1999; Sauvage, 2003). Many studies have found that innovation is the most important tool for enterprises to keep their competitive advantage (Damanpour and Evan, 1984; Kimberly and Evanisko, 1981). However, most research about innovation focused on manufacturing industries though increasing attention has been paid to innovation in service industries recently (Gallouj, 2002; Howells and Tether, 2004; Miles, 2004). The survival of an enterprise in the age of knowledge-based economy depends on how to improve their organizational innovation capability. Technological innovation is the key variable and means of differentiation between logistics service providers (Sauvage, 2003). Logistics service providers can increase their performance by employing new technologies (Speakman, 2002). They should employ new information technologies to raise their service capability in the e-commerce age (Nixon, 2001). Chapman *et al*. (2003) suggest that the logistics industry should pay more attention to innovation in logistics service and the innovation in logistics can be implemented through technology, knowledge and relationship networks. Adopting new technologies might enable logistics service providers to enhance their service abilities.

As a result, technological innovation is important for China's logistics industry. Most operations of China's logistics service providers are labor-intensive and rely on the input of a large number of service workers. Nowadays, in the age of knowledge-based economy, how China's logistics service providers can be transformed from labor-intensiveness into knowledge-intensiveness, and how they can make full use of the market intelligence to create knowledge and further take advantage of the knowledge to innovate products and services to promote the competence of organizations, are the topics worth taking into deep consideration. Continuous technological advancement can assist China's logistics industry to revolutionize the way they operate and conduct their business. When logistics service providers draw up strategies for adopting technological innovations, they should know what factors will influence the adoption of technological innovations. However, there is still a lack of empirical research on technological innovation for China's logistics industry. Therefore, the main purpose of this paper is to explore the determinants of adopting technological innovations for the logistics industry in China.

The next section presents a summary of innovation in logistics technologies and the third section introduces the theoretical foundations of the determinants of innovation. The fourth section gives a description of the research methodology, while the fifth section focuses on the analysis of the results and the discussion of the findings. The final section gives conclusions and research's implications.

Innovation in Logistics Technologies

Definition of Innovation

What is innovation? One of the problems in managing innovation is variation in what people understand by the term. Drucker (1985) defines innovation as the specific tool of entrepreneurs, the means by which they exploit change as an opportunity for a different business or service. It is capable of being presented as a discipline, capable of being learned, capable of being practiced. Betz (1997) assumes that innovation is to introduce a new or improved product, process, or service into the marketplace. Tidd *et al*. (1997) define innovation as "*a process of turning opportunity into new ideas and putting these into widely used practice*." Afuah (1998) proposes that innovation is the use of new technical and administrative knowledge to offer a new product or service to customers. The product or service is new in that its cost is lower, its attributes are improved, it now has attributes it never had before, or it never existed in that market before.

Therefore, we can conclude that innovation is any practices that are new to organizations, including equipments, products, services, processes, policies and projects (Damanpour, 1991; Kimberly and Evanisko, 1981). The new product or service itself is called an innovation, reflecting the fact that it is the creation of new technical or administrative knowledge, or it is new to customers. The new technical or administrative knowledge that is used to offer the new product or service can underpin any of the chain of activities that the firm must perform in order to offer the new product. It can be in the design of the product or service or in the way the product or service is advertised.

Past research has argued that distinguishing types of innovation is necessary for understanding organizations' adoption behavior and identifying the determinants of innovation in them (Downs and Mohr, 1976; Knight, 1967; Rowe and Boise, 1974). Among numerous typologies of innovation advanced in the relevant literature, the pair of types of innovation, administrative and technological (or technical) innovations, is commonly used (Damanpour, 1991). Technological innovation pertains to products, services, and production process technology; it is related to basic activities and can concern either product or process (Damanpour and Evan, 1984; Knight, 1967). Administrative innovation involves organizational structure and administrative processes; it is indirectly related to the

basic work activities of an organization and is more directly related to its management (Damanpour and Evan, 1984; Kimberly and Evanisko, 1981; Knight, 1967). This paper will focus on the technological innovations in the logistics industry.

Innovation in Logistics Technologies

Logistics is the supply of service or product to the demander or demanding unit at the right time, with the right quantity, in the right quality, with the right cost and at the right place. The Council of Supply Chain Management in USA defines "logistics management" as "*a kind of programming, implementing and controlling process dealing with the flow from the primitive occurring point to the final consumption point and the storage efficiency as well as the cost benefit of raw material, half-finished product, finished product and related information, for the purpose of satisfying the customer's requirement*" (Bowersox and Closs, 1996). Logistics has become an important source of competitive advantage (Day, 1994; Olavarrieta and Ellinger, 1997).

Due to the emergence of the concept of supply chain management, logistics management has attracted more and more attention. Logistics management has become a strategic factor that provides a unique competitive advantage (Christopher, 1993). A supply chain includes all the interactions between suppliers, manufactures, distributors, and customers. The chain includes transportation, scheduling information, cash and credit transfers, as well as ideas, designs, and material transfers. Logistics service providers play an important role in the supply chain. One of the keys to effective supply chain management is to make the logistics function more efficiently in the supply chain (Bowersox *et al*., 2002).

A logistics service provider is a provider of logistics services that performs all or part of a client company's logistics function (Coyle *et al*., 1996; Delfmann *et al*., 2002). To fully satisfy the increasing requirements of customers for one-stop services, many logistics service providers have taken initiatives to broaden the scope of their services (Murphy and Daley, 2001). In addition to transportation and warehousing functions, logistics service providers can also provide other services such as materials management services, information-related services, and value-added services (Berglund *et al*., 1999). Recently, many logistics service providers try to improve their operation efficiency by continuous implementation of information or automation technologies according to their business characteristics (Mason-Jones and Towill, 1999; Sauvage, 2003). The operation processes in logistics service providers, such as distribution centers, have their own features and know-how knowledge. It is important for logistics service providers, in this age of knowledge-based economy, to accumulate and use their skills and knowledge efficiently and consistently. In order to keep the competitive advantage, logistics companies must make use of knowledge more efficiently to make them become innovation-based logistics service providers (Chapman *et al*., 2003).

Technology has traditionally been viewed as the key to productivity in manufacturing; however, technology has assumed greater significance in services recently (Bitner et al., 2000; Howells and Tether, 2004). Technology enables service firms to improve service efficiency and effectiveness. Based on the above discussion about innovation, we think that innovation is a process of turning opportunity into new ideas and of putting these into widely used practice. According to the logistics activities, technological innovations in the logistics industry can be classified into four categories: data acquisition technologies, information technologies, warehousing technologies, and transportation technologies.

(1) Data acquisition technologies: Logistics service providers usually deal with a large amount of goods and data. Data collection and exchange are critical for logistics information management and control. Good quality in data acquisition can help logistics service providers deliver customers' goods more accurately and efficiently. The bar code system and radio frequency identification system (RFID) are acquisition technologies that can facilitate logistics data collection and exchange.

(2) Information technologies: Information technologies are the devices or infrastructures to make communications of business information among several organizations more efficiently. Many logistics managers see the information technology as a major source of improved productivity and competitiveness. Information technologies may increase organizational productivity, flexibility and competitiveness as well as stimulate the development of inter-organizational networks. The information technologies that are commonly used in logistics industry include electronic data interchange (EDI), the Internet, value added network (VAN), point of sales (POS), electronic ordering system (EOS), logistics information system, computer telephony integration, and enterprise information portals.

(3) Warehousing technologies: A warehouse is typically viewed as a place to store inventory. However, in many logistical systems, the role of the warehouse is more properly viewed as a switching facility as contrasted to a storage facility. Warehousing plays an important role in a logistical system. The design of a warehouse management system should address physical facility characteristics and product movement.

The warehousing technologies that are commonly used in logistics industry include automated storage and retrieval system (AS/RS), automatic sorting system, computer-aided picking system, and thermostat warehouse. The automated storage and retrieval system is a mean to high density, hands free buffering of materials in distribution and manufacturing environments and can offer a quick and efficient way to search and move storages from a warehouse.

(4) Transportation technologies: Transportation is one of the most visible elements of logistics operations. Transportation functionality provides the major function of product movement. The major objective of a transportation management system is to move product from an origin location to a prescribed destination while minimizing costs and damage expenses. The movement, at the same time, must take place in a manner that meets customer demands regarding delivery performance and shipment information availability. The transportation technologies that are commonly used in logistics industry include transportation information system, global positioning system (GPS), geographical information system (GIS), radio-frequency communication system, and transportation data recorder. The transportation information system and geographical information system can help logistics managers planning, managing and controlling transportation issues. The global positioning system, and radio-frequency communication system can track and guide drivers during the transportation of products.

Technological Innovation and Supply Chain Performance

Innovation can reinforce competitive advantage for companies in markets where customer preferences change rapidly, where differentiation is limited, and where competition is intense (McAfee, 2002). A substantial body of research links innovation and performance for service industries (de Brentani and Cooper, 1993; Gray *et al*., 2000, Harvey, 2000; Irwin *et al*., 1998; Johne and Storey, 1998; Li and Atuahene-Gima, 2001; Lynn *et al*., 1999). In the logistics literature, it has been shown that logistics services capabilities, such as warehousing and freight bill payment, are drivers for superior performance (Murphy and Poist, 2000). Customer-focused capabilities including responsiveness and flexibility can enhance performance (Zhao *et al*., 2001). Lai (2004) suggests that a logistics service provider with a better service capability attain a higher service performance. Based on the above discussions, the following hypothesis is proposed:

Hypothesis H_1 *China's logistics service providers with a more willingness to adopt technological innovations will attain better supply chain performance.*

Several measures in the evaluation of supply chain performance have been identified (Beamon, 1999; Brewer and Speh, 2000; Chan and Qi, 2003; Gunasekaran *et al*., 2004; Rafele, 2004). Quality, time, flexibility, and cost are primary categories of performance measurements (Neely *et al*., 1995). Based on the available literature, supply chain performance measurements in this study consist of financial indices including profit margin, revenue growth, cost per order, cost per unit, and return on assets, and non-financial indices including order fill rates, order cycle time, delivery time, customer requirements satisfied, number of faults and flexibility.

Determinants of Innovation

A body of research studied the determinants or influencing factors on innovation (Amabile, 1988; Damanpour, 1991; Kimberly and Evanisko, 1981; Tidd *et al*, 1997; Tornatzky and Fleischer, 1990; Wolfe, 1994). Kimberly and Evanisko (1981) suggest that the individual factor, organizational factor, and contextual factor would influence hospital adoption of technological innovation. Kwon and Zmud (1987) classify variables affecting technology adoption into individual, task-related, innovation-related, organizational, and environmental characteristics. Tornatzky and Fleischer (1990) suggest that the adoption and implementation of technological innovation would be affected by the technological context, organizational context, and the external environmental context. Patterson *et al*. (2003) indicate that technology adoption is affected by organizational size, structure, and performance, supply chain strategy, transaction climate, supply chain member pressure, and environmental uncertainty. Scupola (2003) use technological, organizational, and environmental characteristics to explain the adoption of Internet commerce. This paper will investigate the influence of technological, organizational, and environmental factors on the adoption of technological innovations for China's logistics service providers.

Technological Factors

Technologies can be viewed as one kind of knowledge (Grant, 1996). Tsai and Ghoshal (1998) found that an organization will have higher innovative capability when knowledge can be distributed more easily within the organization. The transferability of knowledge or technology will influence technological innovation; technological innovation can be advanced when the technology has higher transferability. The transferability of technology is determined by the explicitness of technology. It is more easily to transfer or share technological knowledge with higher explicitness (Grant, 1996; Teece,

1996). In addition to the explicitness of the technology, how the technology fits with the technologies that a firm already possesses will also be another important technological characteristic (Chau and Tam, 1997; Tornatzky and Fleischer, 1990). Teece (1996) found that technological innovation usually follows a technological paradigm. The cumulative nature of technologies will influence the innovation in technologies. Grant (1996) and Simonin (1999) also concluded that an organization with rich experiences in the application or adoption of related technologies will have higher ability in technological innovation. Therefore we would expect that explicitness and accumulation of logistics technology might influence technological innovation.

Hypothesis H_{2a} *The more the explicitness of the technology, the more likely that China's logistics service providers will adopt innovation in logistics technology.*

Hypothesis H_{2b} *The more the accumulation of the technology, the more likely that China's logistics service providers will adopt innovation in logistics technology.*

Organizational Factors

Much research about organizational behaviors has argued that certain features of organizations themselves, including structures, climates, and cultures of organizations, will influence the adoption of innovation (Kimberly and Evanisko, 1981; Russell and Hoag, 2004; Tornatzky and Fleischer, 1990). Ambile (1988) find that the management skills, organizational encouragement for innovation, and support of innovation resources would help the improvement of organizational innovation. Tornatzky and Fleischer (1990) suggest that informal linkages and communication among the employees, the quality of human resources, top management's leadership behavior and the amount of internal slack resources would significantly influence the adoption of technological innovations. A firm with higher quality of human resources such as better education or training will have higher ability in technological innovation. Therefore we would expect that organizational encouragement and quality of human resources might influence technological innovation.

Hypothesis H_{3a} *The more the organizational encouragement, the more likely that China's logistics service providers will adopt innovation in logistics technology.*

Hypothesis H_{3b} *The higher the quality of human resources, the more likely that China's logistics service providers will adopt innovation in logistics technology.*

Environmental Factors

In addition to technological and organizational factors, the external environment in which a firm conducts its business will also influence the innovative capability (King and Anderson, 1995). Miles and Snow (1978) found that organizations would pay more attention on innovation when they faced environments with higher instability and chaos. Kimberly and Evanisko (1981) concluded the environmental complexity and uncertainty would influence the organizational innovation for hospitals. Damanpour (1991) found that environments with high uncertainties would have positive influence on the relationship between organizational structures and organizational innovation. Zhu and Weyant (2003) suggest that demand uncertainty tends to increase firm's incentive to adopt new technologies. Governmental support is another important environmental characteristic for technological innovation. Government through regulation can both encourage and discourage the adoption of innovation (Scupola, 2003; Tornatzky and Fleischer, 1990). Government can provide financial incentives, pilot projects, and tax breaks to stimulate technological innovation for logistics service providers. Therefore we expect that environmental uncertainty and governmental support might influence technological innovation.

Hypothesis H_{4a} *The more the environmental uncertainty, the more likely that China's logistics service providers will adopt innovation in logistics technology.*

Hypothesis H_{4b} *The more the governmental support, the more likely that China's logistics service providers will adopt innovation in logistics technology.*

Methodology

Based on the above discussions, the research framework is organized around the four main hypotheses, as shown in Figure 1. This research framework will be verified from a questionnaire survey in China's logistics industry. The questionnaire contains six parts: company's information, technological factors, organizational factors, environmental factors, the adoption of technological innovations, and supply chain performance. There are 61 items in the questionnaire. Besides the company's information, the other items were measure using the 5-point Likert scales anchored by 'strongly disagree' and 'strongly agree'. The willingness to innovate or acquire new technologies and the utilization of innovative technologies are used as measurements of adoption of technological innovation.

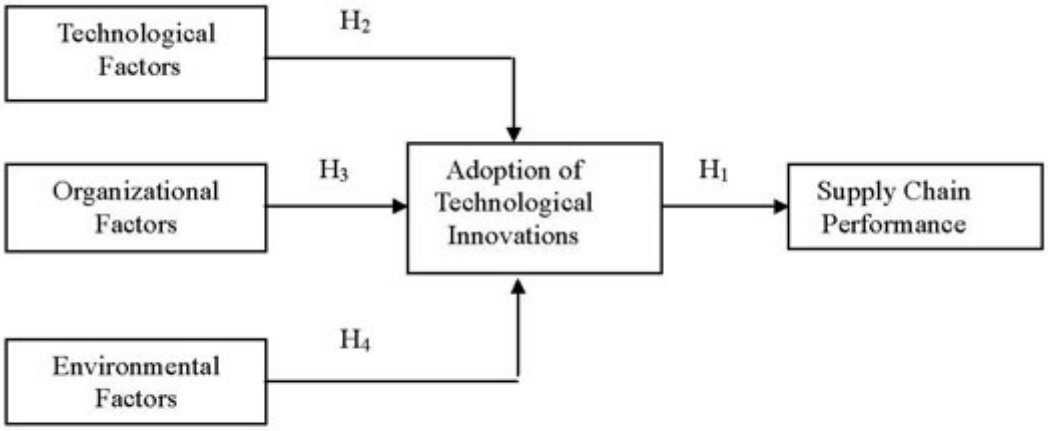

Figure 1 Research Framework

Data Collection and Sample Description

The data to test our hypotheses come from a questionnaire survey of logistics service providers in China. As China becomes a global manufacturing powerhouse, China's central and local governments delivered several policies to reinforce the logistics industry (Jiang, 2002). Moreover, after China's accession into WTO, allowing foreign logistics companies to operate in China more freely boost the growth of China's logistics industry. More and more logistics companies in China begin to adopt technological innovations to increase their logistics service capabilities. However, the logistics industry in China is still in its infancy compared with its counterparts in more developed countries. Ta *et al*. (2000) found that the logistics barriers to international operations in China include the lack of cargo tracing services, the lack of delivery reliability for local carriers, the lack of carrier selection, complicated customs procedures, and geographical fragmentation of transportation networks.

Generally, logistics service providers are companies which carry out logistics activities for their customers. Logistics activities associated with logistics service providers include warehousing, transportation, inventory management, order processing, and packaging (Delfmann *et al*., 2002; Sink *et al*., 1996). The sample frame was drawn from members of the Logistics Council in Beijing, Shanghai and Shenzhen regions because the development of logistics service providers in these three regions are more mature than other regions in China. The Beijing Municipal Government has placed the establishment of a highly effective logistics platform by 2010 in its tenth five-year development plan. The Shanghai Municipal Government has been giving priority to the development of three large-scale logistics parks during its tenth five-year plan period. The Shenzhen Municipal Government plans to develop logistics services into one of the three mainstay industries in the 21st century. Five hundred questionnaires were mailed and/or delivered directly to the sampled companies in each region. In order to get a higher rate of response, we also personally deliver questionnaires to some logistics companies in each area.

In total, 1500 questionnaires were delivered to sampled companies, and 583 questionnaires were returned, 163 in Beijing, 201 in Shanghai and 219 in Shenzhen. Of these respondents, 26 uncompleted or unconfident questionnaires were excluded. The overall response rate is 37.1 percent. The basic information of these companies is shown in Table 1. It can be found that most of logistics service providers in China do not establish the R&D department. Only about 4 percent of the sampling companies have R&D department. In China, most logistics companies belong to small and medium size enterprises.

Table 1

Basic Information of the Sample

	Category	Number	Percentage (%)
Company history (Years)	0~5	389	69.8 %
	6~10	123	22.1 %
	11~20	35	6.3 %
	Above 20	10	1.8 %
Number of employee	Below 50	204	36.6 %
	51~100	186	33.4 %
	101~300	103	18.5 %
	301~500	43	7.7 %
	Above 501	21	3.8 %
Capital (Million, RMB Yuan)	Below 1	133	23.9 %
	1~5	184	33.0 %
	5~10	117	21.0 %
	10~50	76	13.7 %
	Above 50	47	8.4 %
R&D department	Yes	534	95.9 %
	None	23	4.1 %

In this study, the measured scales were submitted to factor analysis. Factors with eigenvalues greater than 1.0 for each characteristic are summarized in Table 2, Table 3 and Table 4. The reliability analysis was also conducted. According to the reliability coefficients shown in Table 5, the smallest value of Cronbach's alpha for this study is 0.7915. This implies that the sampling results are reliable. This implies that the sampling results are reliable. Technological context is factorized by "explicitness of technology" and "accumulation of technology"; organizational context is factorized by "organizational encouragement" and "quality of human resources"; environmental context is factorized by "environmental uncertainty" and "governmental support"; supply chain performance is factorized by "financial" and "non-financial."

Table 2

Result of Factor Analysis for Technological Factors

Items	Factor loadings	
	Factor 1	**Factor 2**
Explicitness of technology (Factor 1)		
It is easy to find books or other resources about the technology.	0.818	0.125
It is easy to understand the technology.	0.783	0.142
It is easy to learn the application of the technology from the books.	0.762	0.163
It does not need too many experiences to learn the technology.	0.714	0.193
Accumulation of technology (Factor 2)		
Our company has implemented many related technologies.	0.109	0.821
It is necessary to have experiences in using related technologies.	0.141	0.774
It is easy to integrate that technology with company's current logistics system.	0.152	0.712
Eigenvalue	4.175	2.819
Variance explained	36.133 %	32.496 %
Accumulated variance explained	36.133 %	68.629 %

Table 3

Result of Factor Analysis for Organizational Factors

Items	Factor loadings	
	Factor 1	**Factor 2**
Organizational encouragement (Factor 1)		
Company's leaders encourage employees to learn new information.	0.832	0.131
Our company provides supports for employees to learn new information.	0.816	0.099
Company's leaders can help employees when they face new problems.	0.776	0.103
Our Company provides rewards for innovative employees.	0.735	0.129
Quality of human resources (Factor 2)		
Employees possess abilities to use technologies to solve problems.	0.100	0.813
Employees can learn new technologies easily.	0.134	0.788
Employees usually provide new ideas for companies.	0.115	0.746
Employees can share knowledge with each others.	0.197	0.701
Eigenvalue	4.231	2.987
Variance explained	36.309 %	32.715 %
Accumulated variance explained	36.309 %	69.024 %

Table 4

Result of Factor Analysis for Environmental Factors

Items	Factor loadings	
	Factor 1	**Factor 2**
Governmental support (Factor 1)		
Government helps training manpower with logistics skills.	0.838	0.091
Government encourages companies to propose projects of logistics technologies.	0.802	0.083
Government relieves the regulation for the logistics industry.	0.776	0.071
Government provides financial support for the development of logistics technologies.	0.711	0.096
Environmental uncertainty (Factor 2)		
Competitors usually provide new logistics services	0.113	0.819
Customers' requirements are diversified	0.103	0.794
The advance in new logistics technologies is quickly	0.102	0.768
Customers' requirements vary quickly	0.093	0.708
Eigenvalue	4.204	2.901
Variance explained	36.243 %	32.579 %
Accumulated variance explained	36.243 %	68.822 %

Table 5

Results of Reliability Analysis

Factors	Cronbach's alpha
Technological context	
Explicitness of technology	α = 0.8126
Accumulation of technology	α = 0.8382
Organizational context	
Organizational encouragement	α = 0.8947
Quality of human resources	α = 0.8164
Environmental context	
Environmental uncertainty	α = 0.8436
Governmental support	α = 0.9079
Supply chain performance	
Financial	α = 0.8291
Non-Financial	α = 0.7915
Adoption of technological innovations	α = 0.8751

Table 6 shows the correlations among these factors and the innovation in logistics technologies. The correlation matrix gives us initial evidences of our hypotheses: technological, organizational and environmental are associated positively with the adoption of technological innovations, and the supply chain performance is positively associated with the adoption of technological innovations. Moreover, the technological, organizational and environmental factors are not highly correlated.

Table 6

Result of Correlation Analysis

Variables	Means	Std	1	2	3	4	5	6	7	8	9
1. Explicitness of technology	3.79	0.89	1.0								
2. Accumulation of technology	3.26	0.93	0.26	1.0							
3. Organizational encouragement	4.01	0.81	0.18	0.25	1.0						
4. Quality of human resources	3.86	0.96	0.25	0.31	0.38	1.0					
5. Environmental uncertainty	3.01	1.05	-0.03	0.06	0.08	0.11	1.0				
6. Governmental support	4.15	0.68	0.09	0.15	0.12	0.08	-0.06	1.0			
7. Adoption of innovations	3.58	1.02	0.41^{+}	0.58**	0.61**	0.66**	0.33	0.71**	1.0		
8. Financial performance	3.37	0.86	0.16	0.21	0.43^{+}	0.51*	-0.21	0.33	0.68**	1.0	
9. Non-Financial performance	3.04	0.94	0.13	0.24	0.40^{+}	0.53*	-0.18	0.28	0.64**	0.44^{+}	1.0

+ $p<0.1$ * $p<0.05$ ** $p<0.01$

Results and Discussions

From the respondent results of the questionnaire survey, this paper firstly investigate the adoption of technological innovations by China's logistics service providers, and then study the influences of technological, organizational and environmental factors on the adoption of technological innovations, and the relationship between the technological innovation and supply chain performance.

Adoption of Technological Innovations for China's Logistics Service Providers

Based on the above illustrations about the innovation in logistics technologies, logistics technologies can be divided into four categories: data acquisition technologies, information technologies, warehousing technologies, and transportation technologies. This paper asked the logistics service providers what kinds of innovative logistics technologies they acquired during the past three years. A summary of the adoption of technological innovations by logistics service providers in China is shown in Table 7. It can be found that almost all respondents acquired innovative information technologies during the past three years. This might be caused by the rapid growth in information and communication technologies over the past decade and by the urgent needs for logistics companies to deal with a great amount data. However, only about one half of the respondents acquired innovative data acquisition technologies such as bar code or RFID technologies.

Table 7

Adoption of Technological Innovations by China's Logistics Service Providers

Logistics technologies	Number (N=557)	Percentage (%)
Data acquisition technologies	312	56.0 %
Information technologies	529	94.9 %
Warehousing technologies	411	73.8 %
Transportation technologies	493	88.5 %

Factors Influencing the Innovation in Logistics Technologies

To find the influence of technological, organizational, and environmental factors on the adoption of technological innovations, the method of regression analysis was used in this study. Based on the factor-analysis results, the technological context consists of explicitness of technology and accumulation of technology; the organizational context consists of organizational encouragement and quality of human resources; the environmental context consists of environmental uncertainty and governmental support. This paper took these six factors as independent variables and the adoption of technological innovation as the dependent variable, and consequently, employed the method of regression analysis to determine their relationship. We also take company history, number of employee and capital size as control variables in the regression analysis. Table 8 shows the results of regression analysis.

Table 8

Standardized Regression Results for the Determinants of Technology Innovation

Dependent variable: Adoption of technological innovations		
Predictors	Coefficient β	t
Control variables		
Company history	0.024	0.748
Number of employee	0.038	0.385
Capital size	0.101	1.597^{+}
Technological context		
Explicitness of technology	0.159	1.701^{+}
Accumulation of technology	0.162	2.733*
Organizational context		
Organizational encouragement	0.201	2.909*
Quality of human resources	0.199	3.521**
Environmental context		
Environmental uncertainty	0.131	1.158
Governmental support	0.216	3.711**
R^2	0.683	
adj R^2	0.579	
F	9.284**	

$^{+}$ $p<0.1$ * $p<0.05$ ** $p<0.01$

Table 8 shows that the capital size of logistics service providers may have positive influences on the adoption of innovative logistics technologies. This implies that logistics service providers with a larger scale may have more willingness to adopt innovative logistics technologies. However, the positive effects are not significant. It can also be found that the technological, organizational and environmental contexts have positive influences on the adoption of technological innovations by China logistics service providers. Explicitness of technology, accumulation of technology, organizational encouragement, quality of human resources, and governmental support all have

significant influences on the adoption of technological innovations. This means that the hypotheses, $\boldsymbol{H_{2a}}$, $\boldsymbol{H_{2b}}$, $\boldsymbol{H_{3a}}$, $\boldsymbol{H_{3b}}$ and $\boldsymbol{H_{4b}}$ are not rejected, but the hypothesis $\boldsymbol{H_{4a}}$ is rejected. Therefore we can conclude that for China's logistics service providers, higher explicitness of technology can help the transfer of technological knowledge within the organization and, therefore, raise the willingness to adopt technological innovations. Logistics companies with rich experiences in the application or adoption of related logistics technologies will have higher willingness to adopt technological innovations. Organizational encouragement can give employees motivation and support to adopt technological innovation. High quality of human resources means that employees are capable of innovation in technologies. Governmental support can encourage and guide logistics service providers to innovate in logistics technologies. The government can draw up public policies to encourage private sector performance improvements through trade and inter-modal policies, infrastructure investment and development, creative financing arrangements, tax incentives, safety regulation, public/private partnerships, and special programs and projects (Morash and Lynch, 2002).

Although environmental uncertainty does not have significant influence on the adoption of technological innovations, the positive effect reveals that China's logistics

service providers still want to adopt innovative logistics technologies to overcome the challenges of environmental uncertainties. Moreover, because most logistics companies in China are small and medium size and providing flexible services to satisfy customers' varying requirements is one major competence for most small and medium businesses, environmental uncertainty is to some extent common to them. Therefore this might be the reason that environmental uncertainty does not significantly influence the adoption of technological innovations by China's logistics industry.

Innovation in Logistics Technologies and Supply Chain Performance

The method of regression analysis is used to examine the influence of adopting innovative logistics technologies on supply chain performance. Company history, number of employee and capital size are also taken as control variables in the regression analysis. Based on the results shown in Table 9, it can be found that the adoption of technological innovations exhibits significantly positive influences on both financial and non-financial supply chain performances. This means that the hypothesis $\boldsymbol{H_1}$ is not rejected. China's logistics service providers with a more favorable attitude toward adopting innovative logistics technologies will attain better supply chain performance.

Table 9

Standardized Regression Results for the Supply Chain Performance

Dependent variables: Supply chain performance				
	Financial		Non-Financial	
Predictors	Coefficient β	t	Coefficient β	t
Control variables				
Company history	0.023	0.930	0.021	0.994
Number of employee	0.019	0.602	0.038	1.003
Capital size	0.039	1.038	0.047	1.106
Adoption of technological innovations	0.213	4.041**	0.201	3.835**
R^2	0.617		0.601	
adj R^2	0.561		0.553	
F	8.935**		8.214**	

$^{+}p<0.1$ * $p<0.05$ ** $p<0.01$

Conclusions

Since the China's government has been actively formulating policies to encourage a stronger linkage between the national economy and the global economy, China has become an important investment destination for multinational corporations. More and more foreign companies invest in China to take advantage of low labor costs and the potentially huge market. However, many foreign investors have faced several logistics problems such as the transportation of materials or products and the flow of information. The logistics cost in China is still high compared to many developed countries. To solve the logistics problems, accelerating the development of the logistics industry is one of the major policies of the China's government.

To improve their logistics services, many logistics companies in China begin to adopt innovative logistics technologies. Advanced technologies and innovations play a critical role in expediting further growth of the logistics industry in China. However, there is a lack of empirical research on the adoption of logistics technologies in China. This paper investigates the determinants of the adoption of technological innovations by China's logistics industry. Based on the research results, it is found that most of China's logistics service providers place emphases on the innovation in information technologies. There is a trend that logistics companies in China will rely more on information technologies to enhance their supply chain management. It is found that China's logistics service providers with a more favorable attitude toward adopting new logistics technologies will attain better supply chain performance. Technological, organizational, and environmental factors significantly affect the adoption of technological innovations by China's logistics industry. It is found that higher explicitness and accumulation of technology can help the transfer of technological knowledge within the organization and can raise the capability to adopt innovative technologies. China's logistics companies can increase their technology innovation abilities by encouraging or supporting their employees to adopt new technologies as well as by training and educating their employees to become intelligent workers. Moreover, the China's government can provide financial incentives, pilot projects, and tax breaks to stimulate the logistics industry to adopt innovative logistics technologies. Technology innovation will be reinforced if the government can provide various supports and resources, and continuous encouragement policies.

This paper only studies the influences of technological, organizational and environmental factors on the adoption of innovative logistics technologies by China's logistics service providers. As we know, logistics service providers cover a wide range of service models. In this study, we did not take the influences of service models of logistics service providers on the adoption of technological innovations. There might be different effects of technological, organizational and environmental factors on the adoption of technological innovations for different logistics service models. It is worthwhile to make a further study on the moderating effect of logistics service models on the adoption of innovative logistics technologies.

About the Authors

Dr. Chieh-Yu Lin got his Ph.D. degree in National Cheng Kung University in Taiwan. He is now the Associate Professor at Department of International Business in Chang Jung Christian University. His research interests include management of technology, supply chain management, logistics management, and electronic business. He has published articles in *International Journal of Information Systems for Logistics and Management*, *Journal of Information & Optimization Science*, *International Journal of Electronic Business Management, Academy of Management Annual Meeting, Journal of Statistics & Management Systems*, and others.

Dr. Yi-Hui Ho earned her Ph.D. degree from the University of Minnesota - Twin Cities. She is now the Assistant Professor at Department of International Business in Chang Jung Christian University. Her research interests include cross-cultural management, business ethics, and performance evaluation. She has published articles in *The Journal of Human Resource and Adult Learning, International Journal of Electronic Business Management, Academy of Management Annual Meeting,* and others.

References

Afuah, A. (1998). *Innovation management: Strategies, implementation, and profits.* New York: Oxford University Press.

Amabile, T. M. (1988). A model of creativity and innovation in organization. In B. M. Staw and L. L. Cummings (Eds.), *Research in Organizational Behavior*, Vol. 10, pp.123-167, Chicago: Aldine Publishing Company.

Beamon, B. (1999). Measuring supply chain performance. *International Journal of Operations & Production Management*, 19(3), 275-292.

Berglund, M., van Laarhoven, P., Sharman, G., & Wandel, S. (1999). Third-party logistics: is there a future? *International Journal of Logistics Management*, 10(1), 59-70.

Betz, F. (1997). *Managing technological innovation: Competitive advantage from change.* New York: John Wiley & Sons, Inc.

Bitner, M. J., Brown, S. W., & Meuter, M. L. (2000). Technology infusion in service encounters. *Journal of the Academy of Marketing Science*, 28(1), 138-149.

Bowersox, D. J., & Closs, D. J. (1996). *Logistical management: The integrated supply chain process.* New York: Mc-Graw-Hill.

Bowersox, D. J., Closs, D. J., & Cooper, M. B. (2002). *Supply chain logistical management.* New York: Mc-Graw-Hill. de Brentani, U., & Cooper, R. G. (1993). Developing successful new financial services for businesses. *Industrial Marketing Management*, 21(3), 231-242.

Brewer, P., & Speh, T. W. (2000). Using the balanced scorecard to measure supply chain performance. *Journal of Business Logistics*, 21(1), 75-93.

Chan, F. T. S., & Qi, H. J. (2003). An innovative performance measurement method for supply chain management. *Supply Chain Management: An International Journal*, 8(3), 209-223.

Chapman, R. L., Soosay, C., & Kandampully, J. (2003). Innovation in logistic services and the new business model: A conceptual framework. *International Journal of Physical Distribution & Logistics Management*, 33(7), 630-650.

Chau, P. Y. K., & Tam, K. Y. (1997). Factors affecting the adoption of open systems: an exploratory study. *MIS Quarterly*, 21(1), 1-24.

China Distribution & Trading. 2005(June). *Recent development of the logistics industry in China (2004-2005)*. Issue 27. Li & Fung Research Centre. (http://www.lifunggroup.com/ research/china_dis02.htm).

Christopher, M. (1993). Logistics and competitive strategy. *European Management Journal*, 11(2), 258-261.

Coyle, J. J., Bardi, E. J., & Langley Jr., J. C. (1996). *The management of business logistics*, 6th ed. New York: West Publishing Company.

Damanpour, F., & Evan, W. M. (1984). Organizational innovation and performance: the problem of organizational lag. *Administrative Science Quarterly*, 29(3), 392-409.

Damanpour, F. (1991). Organizational innovation: a meta-analysis of effects of determinants and moderators. *Academy of Management Journal*, 34(3), 555-590.

Day, G. S. (1994). The capabilities of market-driven organizations. *Journal of Marketing*, 58(4), 37-52.

Delfmann, W., Albers, S., & Gehring, M. (2002). The impact of electronic commerce on logistics service providers. *International Journal of Physical Distribution & Logistics Management*, 32(3), 203-222.

Downs, G. W., & Mohr, L. B. (1976). Conceptual issues in the study of innovation. *Administrative Science Quarterly*, 21(4), 700-714.

Drucker, P. (1985). *Innovation and entrepreneurship*. Cambridge, MA: Harvard Business School.

Gallouj, F. (2002). *Innovation in the service economy: The new wealth of nations*. Cheltenham, UK: Edward Elgar.

Grant, R. M. (1996). Prospering in dynamically-competitive environments: organizational capability as knowledge integration. *Organization Science*, 7(4), 375-387.

Gray, B. J., Matear, S. M., & Matheson, P. K. (2000). Improving the performance of hospitality firms. *International Journal of Contemporary Hospitality Management*, 12(3), 149-155.

Gunasekaran, A., Patel, C., & McGaughey, R.E. (2004). A framework for supply chain performance measurement. *International Journal of Production Economics*, 87, 333-347.

Harvey, M. (2000). Innovation and competition in UK supermarkets. *Supply Chain Management: An International Journal*, 5(1), 15-21.

Howells, J., & Tether, B. S. (2004). *Innovation in services: Issues at stake and trends*. A Report for DG Enterprise of the European Commission, under contract INNO-Studies 2001: Lot 3 (ENTR-C/2001).

Irwin, J. G., Hoffman, J. J., & Geiger, S. W. (1998). The effect of technological adoption on organizational performance: organizational size and environmental munificence as moderators. *The International Journal of Organizational Analysis*, 6(1), 50-64.

Jiang, B. (2002). How international firms are coping with supply chain issues in China. *Supply Chain Management: An International Journal*, 7(4), 184-188.

Johne, A., & Storey, C. (1998). New service development: a review of the literature and annotated bibliography. *European Journal of Marketing*, 32(3), 184-251.

Kanter, R. M. (1988). When a thousand flowers bloom: Structural, collective, and social conditions for innovation in organization. In B. M. Staw and L. L. Cummings (Eds.), *Research in Organizational Behavior*, Vol. 10, pp. 169-211. Chicago: Aldine Publishing Company.

Kimberly, J. R., & Evanisko, M. J. (1981). Organizational innovation: the influence of individual, organizational, and contextual factors on hospital adoption of technological and administrative innovations. *Academy of Management Journal*, 24(4), 689-713.

King, N., & Anderson, N. R. (1995). *Innovation and change in organizations*. London: Routledge.

Knight, K. E. (1967). A descriptive model of the intra-firm innovation process. *Journal of Business*, 40(4), 478-496.

Kwon, T.H., & Zmud, R.W. (1987). Unifying the fragmented models of information systems implementation. In R.J. Boland and Hirschheim, R.A., (Eds), *Critical Issues in Information Systems Research*, pp. 887-898, New York: John Wiley.

Lai, K. H. (2004). Service capability and performance of logistics service providers. *Transportation Research Part E*, 40(5), 385-399.

Li, H., & Atuahene-Gima, K. (2001). Product innovation strategy and the performance of new technology ventures in China. *Academy of Management Journal*, 44(6), 1123-1134.

Lieb, R., & Miller, J. (2002). The use of third-party logistics services by large US manufacturers: the 2000 survey. *International Journal of Logistics: Research and Applications*, 5(1), 1-12.

Lynn, G. S., Maltz, A. C., Jurkat, P. M., & Hammer, M. D. (1999). New media in marketing redefine competitive advantage: a comparison of small and large firms. *Journal of Services Marketing*, 13(1), 9-20.

Mason-Jones, R., & Towill, D. R. (1999). Using the information decoupling point to improve supply chain performance. *The International Journal of Logistics Management*, 10(2), 13-26.

McAfee, A. (2002). The impact of enterprise information technology adoption on operational performance: an empirical investigation. *Production and Operations Management*, 11(1), 33-53.

McGinnis, M. A., & Kohn, J. W. (2002). Logistics strategy-revised. *Journal of Business Logistics*, 23(2), 1-17.

Miles, I. (2004). Innovation in services. In J. Fagerberg, D. Mowery, and R. Nelson (Eds.) *Understanding Innovation*, Oxford: Oxford University Press.

Miles, R. E., & Snow, C. C. (1978). *Organizational Strategy, Structure, and Process*. New York: McGraw-Hill.

Morash, E. A., & Lynch, D. F. (2002). Public policy and global supply chain capabilities and performance: a resource-based view. *Journal of International Marketing*, 10(1), 25-51.

Murphy, P. R., & Daley, J. M. (2001). Profiling international freight forwarders: an update. *International Journal of Physical Distribution & Logistics Management*, 31(3), 152-168.

Murphy, P. R., & Poist, R. F. (2000). Third-party logistics: some user versus provider perspective. *Journal of Business Logistics*, 21(1), 121-131.

Neely, A. Gregory, M., & Platts, K. (1995). Performance measurement system design. *International Journal of Operations and Production Management*, 15(4), 80-116.

Nixon, M. (2001). Innovations in logistics technology: generating top-line value and bottom-line ROI. *World Trade*, 14, 62-64.

Olavarrieta, S., & Ellinger, A. E. (1997). Resource-based theory and strategic logistics research. *International Journal of Physical Distribution and Logistics Management*, 27(9/10), 559-587.

Patterson, K. A., Grimm, C. M., & Corsi, T. M. (2003). Adopting new technologies for supply chain management. *Transportation Research Part E*, 39, 95-121.

Rafele, C. (2004). Logistic service measurement: A reference framework. *Journal of Manufacturing Technology Management*, 15(3), 280-290.

Rowe, L., & Boise, W. B. (1974). Organizational innovation: current research and evolving concepts. *Public Administration Review*, 34, 284-293.

Russell, D. M., & Hoag, A. M. (2004). People and information technology in the supply chain: social and organizational influences on adoption. *International Journal of Physical Distribution & Logistics Management*, 34(1/2), 102-122.

Sauvage, T. (2003). The relationship between technology and logistics third-party providers. *International Journal of Physical Distribution & Logistics Management*, 33(3), 236-253.

Scupola, A. (2003). The adoption of Internet commerce by SMEs in the south of Italy: An environmental, technological and organizational perspective. *Journal of Global Information Technology Management*, 6(1), 52-71.

Simonin, B. L. (1999). Transfer of marketing know-how in international strategic alliances: an empirical investigation of the role and antecedents of knowledge ambiguity. *Journal of International Business Studies*, 30(3), 463-90.

Sink, H. L., Langley, C. J. Jr., & Gibson, B. J. (1996). Buyer observations of the US third-party logistics market. *International Journal of Physical Distribution & Logistics Management*, 26(3), 36-46.

Speakman, J. P. (2002). Innovation leads to new efficiencies. *Logistics Management*, 41, 71.

Ta, H. P., Choo, H. L., & Sum, C. C. (2000). Transportation concerns of foreign firms in China. *International Journal of Physical Distribution & Logistics Management*, 30(1), 35-53.

Teece, D. J. (1996). Firm organization, industrial structure, and technological innovation. *Journal of Economic Behavior and Organization*, 31(2), 193-224.

Tidd, J. Bessant, J., & Pavitt, K. (1997). *Managing innovation: Integrating technological, market, and organizational change*. New York: John Wiley & Sons.

Tsai, W., & Ghoshal S. (1998). Social capital and value creation: the role of intra-firm networks. *Academy of Management Journal*, 41(4), 464-476.

Tornatzky, L. G., & Fleischer, M. (1990). *The process of technological innovation.* Lexington, MA: Lexington Books, Lexington.

Wolfe, R. A. (1994). Organizational innovation: review, critique and suggested research directions. *Journal of Management Studies*, 31(3), 405-431.

Zhao, M., Droge, C., & Stank, T. P. (2001). The effects of logistics capabilities on firm performance: customer-focused versus information-focused capabilities. *Journal of Business Logistics*, 22(2), 91-107.

Zhu, K., & Weyant, J. P. (2003). Strategic decisions of new technology adoption under asymmetric information: a game-theoretic model. *Decision Sciences*, 34(4), 643-675.