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Knowledge transfer and competitive advantage on environmental uncertainty: An empirical study of the Taiwan semiconductor industry

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Abstract

This study investigates the inter-relationships among environmental uncertainty, knowledge transfer, and competitive advantage. Based on 176 subjects from the R&D and manufacturing department of 56 Taiwan semiconductor companies, this paper implements a structural equation model to test the research framework and hypotheses. It finds that knowledge transfer could develop semiconductor firms' core competence and then build their own competitive advantage. In addition, this study considers that environmental uncertainty is a vital factor during knowledge transfer. Research results indicate that the partially mediated model shows good model fitness for this relationship. In addition, the relationship between environmental uncertainty and knowledge transfer is negative, and knowledge transfer and competitive advantage have a positive relationship. This means that environmental uncertainty could hinder knowledge transfer and lead semiconductor firms to develop knowledge by themselves. Therefore, knowledge transfer to semiconductor firms is very important for technological and knowledge management activity in this rapidly changing industry environment.

Keywords: Knowledge transfer; Competitive advantage; Environmental uncertainty; Knowledge management; Structural equation model

1. Introduction

Taiwan's semiconductor (or integrated circuit, IC) capacity for the year 2000 is NT$ 714.4 billion, ranking fourth in the world, behind only the US, Japan, and Korea. Taiwan's IC foundry capacities lead the world in various aspects (ITRI, 1999–2001). The specialized and vertically collaborative relationship in the Taiwanese semiconductor industry (Chang et al., 1994) is unique in the domestic marketplace and is also distinct from the semiconductor industry in Japan or Korea, where emphasis is on "vertical integration". In this sophisticated vertical disintegration system, the upstream and downstream players are each dedicated to specialized technologies in their own domain, with adequate responsive speed and without unwanted investment burdens. With such sophisticated links in business operation, more knowledge exchange and technology assimilation occurs.

How to obtain knowledge or technology effectively from a counterpart is an important skill to build competitive advantages (Lambe and Spekman, 1997; Phan and Peridis, 2000). Furthermore, a growing body of empirical evidence indicates that organizations that are able to transfer knowledge effectively from one unit to another within the organization are more productive and more likely to survive than organizations that are less adept at knowledge transfer (Baum and Ingram, 1998). Prior studies on knowledge transfer can be divided into two categories. One is how the firms can acquire knowledge through different mechanism, such as strategic alliances (Simonin, 1999, 2004), knowledge transfer from an MNC parent to its subsidiaries (Minbaeva et al., 2003; Jensen and Szulanski, 2004; Minbaeva, 2005), and how knowledge can be acquired from joint ventures (Dhanaraj et al., 2004). Another branch of research investigated the variables which affect knowledge transfer, such as absorptive capacity (Minbaeva et al., 2003), strategic intent (Simonin, 2004), knowledge attributes (Nonaka and Takeuchi, 1995), trust (Wang et al., 2004), and management mechanism (Minbaeva et al., 2003; Bjorkman et al., 2004; Minbaeva,

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2005). Previous studies have generally considered knowledge transfer as an output variable. However, few articles have examined how firms can build and sustain competitive advantage through knowledge transfer. In order to investigate this issue, this study examines the interrelationship among environmental uncertainty, knowledge transfer and competitive advantage. In addition, Cavusgil et al. (2003) found that most research on knowledge management has been limited to knowledge transfer within individual level. This study aims at exploring knowledge transfer among independent firms in Taiwan semiconductor industry. Furthermore, we did not exclude small firms in our sample just because in high-tech industry small firms experience resource deficiency, but they are the harbingers of radically new product and process change (Walsh and Kirchhoff, 2002; Mansfield, 1968).

The rest of the paper is organized as follows. Section 2 discusses the previous literature and proposes the research framework and hypotheses. Section 3 presents the research methodology. Section 4 illustrates the research results, while discussions and future works are presented in Section 5. Finally, a brief conclusion is contained in the last section.

2. Literature review

2.1. Environmental uncertainty

Knowledge faces numerous barriers to its transfer from originator to user, and so it is relatively immobile (Kogut and Zander, 1992). The obstacles between knowledge senders and receivers are caused by knowledge attributes. There are many terms in previous studies to describe this phenomenon such as "knowledge ambiguity" (Simonin, 1999), "causal ambiguity" (Lippman and Rumelt, 1982) and "sticky information" (von Hippel, 1994). The cause of this ambiguity is always due to the fact that knowledge is tacit and complex (Reed and DeFillippi, 1990; Simonin, 1999).

Reviewing the previous studies on ambiguity, Reed and DeFillippi (1990) found that ambiguity might be derived from tacitness, complexity, and specificity. Simonin (1999) indicates that tacitness, complexity, cultural distance, and organizational distance are all positively related to ambiguity, which further indicate that ambiguity is negatively related to knowledge transfer. Heiman and Nickerson (2004) describe that based on transaction cost economics (TCE), increasing knowledge transparency can be accomplished by effective knowledge management practices; although this gives rise to opportunism hazards, which are safeguarded against by economizing governance choice. In addition, when an advantage is based on competencies that have causally ambiguous characteristics, then it will be difficult for competitors to overcome the advantage by imitation (Reed and DeFillippi, 1990). King and Zeithaml (2001) clarify causal ambiguity into linkage ambiguity and characteristic ambiguity, finding that linkage ambiguity is negatively associated with firm performance and that causal ambiguity may be negatively or positively associated with firm performance. In addition, Simonin (2004) noted that the more tacit the partner's knowledge, the greater the degree of knowledge ambiguity. In addition, the greater the degree of knowledge ambiguity, and more protective the partner is of its knowledge, the lower the level of knowledge transfer.

Accordingly, ambiguity could hinder knowledge transfer and directly have a negative effect on organization performance and competitive advantage. In addition, ambiguity may result from tacitness, complexity, specificity, and governance choice.

2.2. Knowledge transfer

Knowledge transfer as the process where "complex, causally ambiguous set of routines" are "recreated and maintained" in a new setting." (Szulanski, 1996). Knowledge transfer in an organization is defined as a process through which one unit (e.g. group, department, or division) is affected by the experience of another (Argote and Ingram, 2000). Wang et al. (2004) describe that knowledge transfer is the process of a systematically organized exchange of information and skills between entities. Szulanski (2000) proposes five basic elements of knowledge transfer, including the source, recipient, channel, message, and context. Knowledge transfer in this study refers to successful knowledge transfer whereby the recipient unit accumulates and assimilates new knowledge (Wang et al., 2004). Therefore, this study defines knowledge transfer as the process by which knowledge receivers acquire knowledge from providers so that it could accumulate and renew productive capability.

Knowledge can be classified as either explicit or tacit (Polanyi, 1967). Explicit knowledge has the character a public good, and it can be easily coded and transferred. Tacit knowledge is encoded knowledge and resides in a firm's system. Although tacit knowledge is important but difficult to interpret and transfer from one firm to another, it can be an important resource to build sustained competitive advantage. Transferring employees is generally seen as a powerful mechanism for facilitating knowledge transfer within organizations (Galbraith, 1990). Since individuals are able to adapt and restructure knowledge so that it applies to new contexts (Allen, 1977). On the other hand, individuals are also able to transfer both tacit and explicit knowledge to new contexts (Berry and Broadbent, 1984, 1987). An empirical study found that the mobility of engineers between firms could contribute the knowledge transfer of innovations in the American semiconductor industry (Almeida and Kogut, 1999). Cummings (2004) also described that group members who engage in information exchange with customers, organizational experts and others outside of the group are positively related to performance.

From the social capital view, the concept has since been applied in a wide range of intra- and inter-organization studies (Burt, 1992; Nahapiet and Ghoshal, 1998). We follow Nahapiet and Ghoshal (1998) in arguing that social capital facilitates knowledge acquisition and exploitation by affecting conditions necessary for the creation of value through the exchange and combination of existing intellectual resources. Yli-Renko et al. (2001) also found that the more social capital a young technology-based firm develops in the relationship, the more likely it is to acquire new knowledge and exploit it as a basis of competitive advantage. From this view, knowledge transfers from inter-organizational relationships as a source of competitive advantage.

On the other hand, knowledge transfer from inter-organization can be view as a kind of learning. Bapuji and Crossan (2004) suggested external learning occurs in the form of congenital learning (a new firm learning from the past experience of other firms in the industry), vicarious learning (firms learning from the experience of other firms) and inter-organizational learning. Inter-organizational learning is that organizational learning occurs through vicarious learning and also when organizations interact with other firms through alliances and joint ventures. Knowledge acquired from other organization, in turn, facilitates further learning (Nonaka and Takeuchi, 1995). Pramongkit et al. (2000) recommended that clusters of industries with good learning potential could be given more encouragement and intensively emphasized relative to other clusters of industries with poor learning potential. The feature in Taiwan semiconductor industry is form clusters; therefore, we argue that if firms in the clusters exploit their opportunity to acquire new knowledge from other company, they will accumulate their competitive advantage.

2.3. Competitive advantage

A recent trend in the field of strategic management has been to emphasize the role of organizational knowledge as a basis of the competitive advantage of particular organizations (Argote and Ingram, 2000). The resource-based view (RBV) of the firm defines a strategic asset as one that is rare, valuable, imperfectly imitable and non-substitutable; RBV puts organizational knowledge in a pre-eminent position as a principal source of competitive advantage (Barney, 1991). From the knowledge-based view (KBV), knowledge-based competitive advantage is sustainable because the more a firm already knows, the more it can learn (Zack, 1999). Therefore, knowledge is an important resource to build sustainable competitive advantage.

In addition, Argote and Ingram (2000) consider that knowledge transfer in organizations manifests itself through changes in the knowledge or performance of the recipient units. Thus, knowledge transfer can be measured by measuring changes in knowledge or changes in performance. However, Lyles and Salk (1996) considered performance in terms of accumulated competencies may prove to be more closely linked with knowledge acquisition than business performance.

On the other hand, knowledge assets in an organization have a direct influence on the performance of knowledge transfer in the organization (Syed-Lkhsan and Rowland, 2004). If a firm has a core competence superior to its competitors, it can build competitive advantage (Cohen and Levinthal, 1990). Therefore, knowledge transfer can develop core competence, improving organization performance and contributing to the competitive advantage.

2.4. Hypothesis

2.4.1. Environmental uncertainty and competitive advantage

King and Zeithaml (2001) suggest that "characteristic ambiguity" focuses on the characteristics of competencies that can be simultaneous sources of advantage and ambiguity and that it has a negative relation to organizational performance (Reed and DeFillippi, 1990). In this study, the ambiguity and complexity in an environmental uncertainty is similar to the "characteristic ambiguity" because ambiguity and complexity are always caused by knowledge attributes. Lin (2003) investigated how firms in developing countries with limited R&D resources can gain sustainable competitive advantage through technology transfer. He found that there is causal ambiguity of the transferred technology, which is negatively associated with a firm's technological learning performance after technology transfer. Accordingly, the following hypothesis is suggested.

H1. Environmental uncertainty has an effect on competitive advantage.

2.4.2. Environmental uncertainty and knowledge transfer

Zander (1991) found that the tacit-articulated dimension of knowledge had an important impact on the smoothness of knowledge transfer process. The perception of a source's trustworthiness will be positively related to the accuracy of the reproduction of the template. However, as causal ambiguity increases, the positive relationship between the perception of a source's trustworthiness and the level of accuracy of the reproduction of the template will first weaken and then, under conditions of high causal ambiguity, turn negative (Szulanski et al., 2004). Simonin (2004) found that the greater the degree of knowledge ambiguity, the lower the level of knowledge transfer and the more tacit the partner's knowledge, the greater the degree of knowledge ambiguity. Simonin (2004) also indicated that when the partner is more protective of its knowledge, the level of knowledge transfer is lower. In addition, Heiman and Nickerson (2004) describe that, based on TCE, increasing knowledge transparency via knowledge management practices, however, gives rise to opportunism hazards, which are safeguarded against by

economizing governance choice. According to these studies, this study proposes the second hypothesis.

H2. Environmental uncertainty has a negative influence to knowledge transfer.

2.4.3. Knowledge transfer and competitive advantage

Dhanaraj et al. (2004) investigated knowledge transfer between the foreign parent and international joint venture (IJV). They suggested that knowledge transfer from the foreign parent could have a positive impact on performance in both young and mature IJVs. Nakamura and Nakamura (2004) also present empirical evidence that transfer of intangible assets from foreign to host country partners contributes to the performance of the host country partner firms. Based on the KBV, knowledge can develop core competence and build sustained competitive advantage. The relational embeddedness on organizations has an influence on knowledge accumulation (Dhanaraj et al., 2004). Thus, the hypothesis is proposed as follows.

H3. Knowledge transfer has a positive effect on competitive advantage.

3. Research methodology

3.1. Research framework

This study investigates the inter-relationships among environmental uncertainty, knowledge transfer, and competitive advantage. According to literature review, the research framework and hypotheses are presented in Fig. 1.

3.2. Sampling

The sampling frame on this study is based on the "Taiwan semiconductor industry list" which is published by the Industrial Development Bureau of the Taiwan Ministry of Economic Affairs, on October 2003. This study chooses IC design, IC manufacturing, and IC packaging and testing firms as the data source, including a total of 338 semiconductor companies. Thus, this study used convenient sampling to collect data by sending questionnaires to employees and managers of R&D and manufacturing departments. In order to increase the response rate, follow-up letters, emails and phone calls were used after one week. A total of 500 questionnaires were mailed. The resulting 176 valid and complete questionnaires from 56 companies were used for quantitative analysis. Thirty-six percent of firms which returned our questionnaire represent a useable response rate of 35.2%. Most respondents were from the R&D department. The IC design, IC manufacturing, and IC packaging and testing firms included in this study comprise 35.8%, 15.9%, and 48.2%, respectively.

3.3. Measurement

A 5-point Likert scale (1 totally disagree to 5 totally agree) was used. The questionnaire was refined based on a pilot study conducted with two managers in the area of knowledge management. The format and content of the questionnaire were initially developed from thorough literature review, and pre-tested using business contacts familiar with the issue of knowledge transfer.

3.3.1. Environmental uncertainty

The three dimensions of environmental uncertainty are ambiguity, complexity, and partner protectiveness (Simonin, 1999). The definition of environmental uncertainty is that due to ambiguity, complexity, and partner protectiveness, knowledge cannot be easily transferred between the organizations. This paper uses two items to measure the ambiguity: (1) know-how held by the knowledge provider is easily transferable back to the firm, and (2) the process know-how held by knowledge provider is clear (composite reliability = 0.66). Complexity is considered to be items where the knowledge provider's process know-how is the product of many inter-dependent techniques, routines, individuals, and resources. Two items were used to measure partner protectiveness: (1) restriction of the sharing of relevant information concerning its process know-how, and (2) protectiveness of its process know-how (composite reliability = 0.56).

3.3.2. Knowledge transfer

The three dimensions of knowledge transfer are organizational knowledge transfer, group movements, and

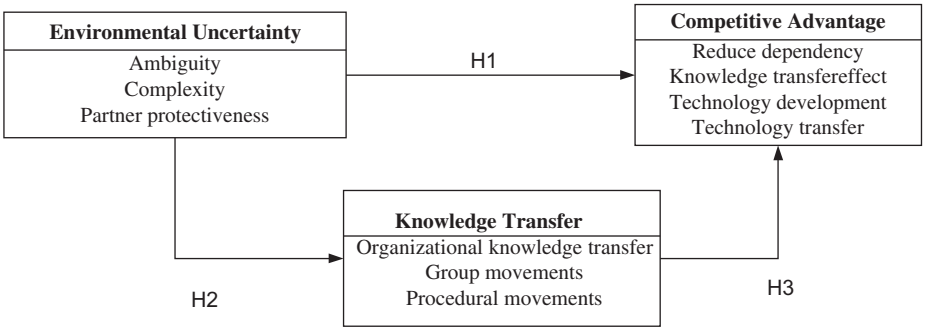

Fig. 1. Research framework.

procedural movements (Yang, 2000; Cheng and Li, 2001). This study defines that knowledge transfer is the process of knowledge transfer from provider to receiver that helps to improve its capabilities. Six items were used to measure organizational knowledge transfer: always sharing their knowledge, solving problems, always providing related documents, showing the way to do the work directly, always giving advice during discussion, and always sharing their own experiences (composite reliability = 0.78). Group movements were assessed using four items: always having group discussion, building groups mutually and sharing knowledge, solving problems through the group, and resolving problems through common expertise (composite reliability = 0.76) Finally, this study used five items to measure the procedural movements. Items included: setting the project goals; planning the project details; clear division of authority between the two parties; always documenting communication; using a database to store the files, documents, and report for reference (composite reliability = 0.72).

3.3.3. Competitive advantage

Competitive advantage can be evaluated by the four dimensions of reduced dependency, knowledge transfer effect, technology development, and technology transfer (Cheng, 2003). The definition of competitive advantage is that an organization acquiring knowledge from outsiders can strengthen its core competences and develop the organization's own competitive advantage. Three items were used to measure reduce dependency: knowledge transfer can help develop R&D capabilities; after knowledge transfer, new technologies could replace old ones; and after knowledge transfer then R&D times would be shortened. The knowledge transfer effect focuses on increasing profits and developing competitive advantage. This study use three items to measure the technology development: the product quality is unique and meets the customers' expectations, continual transfer of newly technology and equipment to improve technology ability, new technology and original technology is combined to create new core technology. Finally, this study use three items to measure the technology transfer: employees have high satisfaction, there are smooth communication channels, and there are excellent employees.

4. Results

LISREL's 8.7 maximum likelihood program (Joreskog and Sorbom, 1996) was implemented to test the theoretical model proposed, as shown in Fig. 1. This structural equation model approach is characterized by its flexible interplay between theory and data, as well as its bridging of theoretical and empirical knowledge for a better understanding of the real world (Fornell, 1982). Such analysis allows for modeling based on both latent (unobservable) variables and manifest (observable) variables, which is a property well suited for the hypothesized model, where most of the represented constructs are abstractions of unobservable phenomena. Furthermore, structural equation modeling considers errors in measurement, variables with multiple indicators, and multiple-group comparisons.

Table 1 displays each of the means, standard deviations and correlation coefficient of the research variables, to use as analysis of the significance level of the relationship that exists between the analyzed aspects.

4.1. Measurement model

In terms of the quality of measurement model for the full sample, the constructs display satisfactory levels of reliability, as indicated by composite reliabilities ranging from 0.56 to 0.84 (Nunnally, 1978). Convergent validity can be judged by considering both the significance of the factor loading and *t*-values. This study estimates the separated models for the confirmatory analysis. All the multi-items constructs fit this criterion, and the loading is significantly related to its underlying factor (*t*-values greater than 1.96) in support of convergent validity (see

Table 1
Means, standard deviations, and correlations of research dimensions

Dimensions	X1	X2	X3	Y1	Y2	Y3	Y4	Y5	Y6	Y7
Ambiguity (X1)	(0.668)									
Complexity (X2)	0.045	*								
Partner protectiveness (X3)	0.186*	0.297**	(0.563)							
Organizational knowledge transfer (Y1)	−0.203*	0.356**	0.093	(0.789)						
Group movements (Y2)	−0.097	0.328**	0.099	0.590**	(0.769)					
Procedural movements (Y3)	−0.156*	0.260**	0.199**	0.622**	0.566**	(0.721)				
Reduce dependency (Y4)	0.02	0.411**	0.169*	0.512**	0.418**	0.421**	(0.655)			
Knowledge transfer effect (Y5)	−0.02	0.383**	0.104	0.437**	0.387**	0.346**	0.703**	(0.841)		
Technology development (Y6)	−0.069	0.326**	0.260**	0.401**	0.384**	0.362**	0.512**	0.473**	(0.638)	
Technology transfer (Y7)	0.064	0.210**	0.144	0.399**	0.358**	0.339**	0.355**	0.296**	0.549**	(0.718)
Means	3.434	3.801	3.579	3.483	3.514	3.518	3.878	3.585	3.570	3.664
SD	0.492	0.701	0.694	0.554	0.609	0.568	0.537	0.733	0.608	0.710

*Significant at $P<0.1$.
**Significant at $P<0.05$.

Table 2). To assess discriminate validity, a series of χ^2 difference tests on the factor correlations among all the constructs (Anderson and Gerbing, 1988). This was done for one pair of variables at a time by constraining the estimated correlation parameter between them to 1.0 and then performing a χ^2 difference test on the values obtained for the constrained and unconstrained models (Anderson and Gerbing, 1988). The resulting significant difference in χ^2 indicates that the two constructs are not perfectly correlated and that discriminate validity is achieved (Bagozzi and Phillips, 1982). Based on Table 3, most of the χ^2 difference in this study is greater than 3.84, except for the environmental uncertainty variable, where this is a good evidence for the dimensions' discriminate validity.

4.2. Model competition

In order to choose the best model, this study uses model competition to compare each model and chooses the best one based on its model fitness. Two competitive models, the completely mediating model and the direct effect model are proposed for comparison with the hypothetical model and the partially mediating model. The research findings are shown on Table 4.

For the complete mediating model and direct effect model, the fitted indexes of goodness of fit (GFI), NFI, CFI, and PGFI are almost completely consistent. Considering the partially mediating model, all model fitness are superior to the other two competitive models. This indicates that the partially mediating model is the best model in this study.

Table 2
Reliability and convergent validity

Variables	Dimensions	Items	Cronbach α	Factor loading (λ)	*t*-value
Knowledge transfer	Organizational knowledge transfer	6	0.7899	0.39–0.56	6.18–9.95
	Group movements	4	0.7690	0.46–0.66	7.70–11.43
	Procedural movements	5	0.7210	0.38–0.56	6.44–8.71
Environmental uncertainty	Ambiguity	2	0.6689	0.29–0.53	3.61–5.57
	Complexity	1	—	0.7	18.66
	Partner protectiveness	2	0.5634	0.38–0.72	4.87–6.37
Competitive advantage	Reduce dependency	3	0.6555	0.37–0.5	6.24–10.06
	Knowledge transfer effect	2	0.8417	0.60–0.75	11.96–13.7
	Technology development	3	0.6381	0.46–0.52	7.31–8.44
	Technology transfer	2	0.7188	0.56–0.65	8.89–9.65

Table 3
Discriminate validity

Variables	Model	χ^2	d.f.	$\Delta\chi^2$
Knowledge transfer	Unconstrained model	294.356	87	
	Organizational knowledge transfer—group movements	325.249	88	30.893
	Organizational knowledge transfer—procedural movements	298.003	88	3.647
	Group movements—procedural movements	318.519	88	24.163
Environmental uncertainty	Unconstraint model	8.471	3	
	Ambiguity—complexity	8.471	3	0
	Ambiguity—partner protectiveness	14.321	4	5.85
	Complexity—partner protectiveness	10.26	3	1.789
Competitive advantage	Unconstraint model	54.899	29	
	Reduce dependency—knowledge transfer effect	59.627	30	4.728
	Reduce dependency—technology development	69.068	30	14.169
	Reduce dependency—technology transfer	102.15	30	47.251
	Knowledge transfer effect—technology development	83.748	30	28.849
	Knowledge transfer effect—technology development	120.178	30	65.279
	Technology development—technology transfer	62.649	30	7.75

Table 4
Model competition

Model	Model fitness						
	χ^2	d.f.	RMR	GFI	NFI	CFI	PGFI
Partially mediating model	27.93	32	0.03	0.97	0.91	0.99	0.56
Complete mediating model	128.02	33	0.064	0.88	0.87	0.9	0.53
Direct effect model	192.42	32	0.029	0.88	0.87	0.90	0.51

4.3. Structural model

After confirming that the theoretical model is the partially mediating model, the structural equation modeling of the LISREL 8.7 is implemented to assess the robustness of the results and the stability of the models. For the structural model, Table 5 illustrates the parameter estimates and GFI indicators. The overall χ^2 value is 27.93, with a degree of freedom equal to 32, and the GFI is 0.97. Although the overall χ^2 is significant, it might be expected with this statistic's sensitivity to sample size (Bagozzi and Yi, 1988; Bentler, 1990). The CFI, which weighs heavily any model misspecification error, is 0.99. The standardized root mean square residual (RMR) is 0.03. The GFI, CFI,

and RMR together suggest that the data fit the hypothesized model reasonably well.

Fig. 2 shows the structural model with the standardized coefficients for the research sample. Hypothesis 1 suggests that environmental uncertainty will have a negative effect on knowledge transfer. The *t*-value for environmental uncertainty to knowledge transfer is 0.32 ($t<1.96$). Hypothesis 1 was unsupported. Hypothesis 2 predicted that knowledge transfer has a positive impact on competitive advantage. The *t*-value for knowledge transfer to competitive advantage is 4.17, so Hypothesis 2 was supported. Finally, Hypothesis 3, supposes that environmental uncertainty would have a negative impact on competitive advantage. The *t*-value for environmental uncertainty to competitive advantage is 0.31, so Hypothesis 3 was not supported.

5. Discussions and future works

5.1. Discussions

By implementing a structural equation modeling approach, this study integrates three constructs, environmental uncertainty, knowledge transfer, and competitive advantage. This study proposes and tests a comprehensive model that explicitly articulates the role of various key variables that in past research received only partial and independent attention. The major findings and the implications are discussed as follows.

Firstly, the results of the structural equation model indicate that knowledge transfer has a significant positive effect on competitive advantage. This finding shows that with more knowledge acquired from other organizations, there is more competence to build sustainable competitive advantage. This finding is consistent with the research by Dhanaraj et al. (2004), which indicated that knowledge transferred from the foreign parent will have a positive impact on performance in both young and mature IJVs. From the RBV, many studies also indicate that knowledge accumulation can develop core competences and then build competitive advantage (Barney, 1991; Lin, 2003). But how the organization can successfully transfer knowledge? Therefore, we advise some step to each company to acquire knowledge from other organizations. We hope

Table 5
Structural parameter estimates and goodness-of-fitness indices

Hypotheses	Paths	Estimate	*t*-value
H1	Environmental uncertainty → competitive advantage (γ_{21})	0.11	0.31
H2	Environmental uncertainty → knowledge transfer (γ_{11})	0.28	0.32
H3	Knowledge transfer → competitive advantage (β_{21})	0.82	4.17**
χ^2(32 d.f.) = 27.93	Standardized RMR = 0.042	GFI = 0.97	CFI = 0.99
p-value = 0.67	NFI = 0.91	AGFI = 0.95	

**Significant at $P<0.05$.

Table 6
Steps for knowledge transfer

Step	Method and process
Step 1	Identify corporate strategy and competitive advantage, then find core competence
Step 2	Drawing knowledge map based on core competence and show the knowledge distribution in company
Step 3	Finding "knowledge gap" and determine what kind of knowledge to be transferred
Step 4	Building knowledge transfer mechanism such as "group movement" with other company then acquire knowledge, especially tacit knowledge
Step 5	Consolidated and classified knowledge, then established knowledge base
Step 6	Building management system, and make the process of knowledge transfer as routine in company

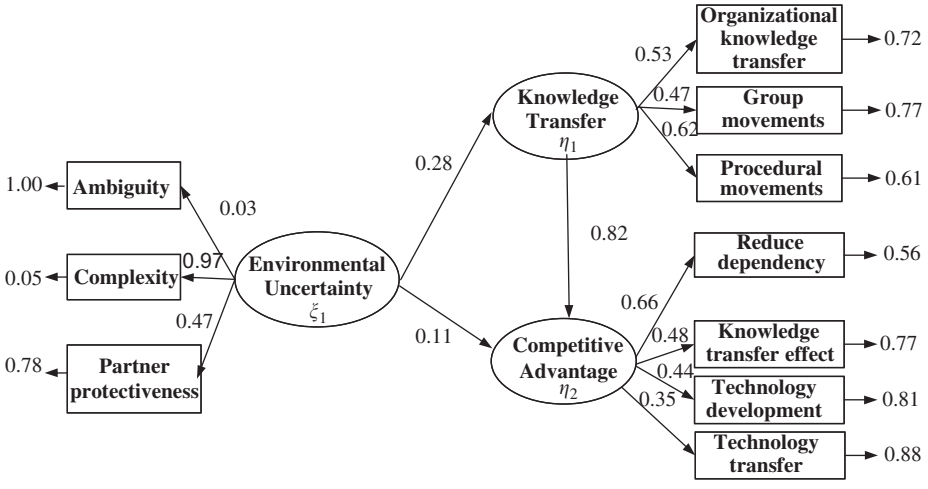

Fig. 2. Partially mediating model.

this guideline will help managers or policy maker for reference when they plan knowledge transfer (see Table 6).

Secondly, in terms of environmental uncertainty, the results of the structural equation model show that the relationship between environmental uncertainty and competitive advantage is insignificant and the coefficient is positive. This study supposes that there are two reasons for this phenomenon. At the first, when respondents replied to the questionnaire, they answered about environmental uncertainty and competitive advantage at the same time. When they answer the items about environmental uncertainty, they may agree that knowledge providers will take some management mechanism to protect their own knowledge. On the contrary, when they responded to the items about competitive advantage, they may have answered the questions on the company side in order to conceal some drawback in their organization. Therefore, these two possible reasons may cause some measurement error in this study. In addition, under high environmental uncertainty, organizations may acquire knowledge from their divisions or subsidiaries. This point also confirmed by Chen and Lin (2004), Heiman and Nickerson (2004), because they found that knowledge providers will protect their knowledge that is related to their core competence. Therefore, firms will tend to develop knowledge by themselves.

Thirdly, the results indicate that there is no evidence to support a relationship between environmental uncertainty and knowledge transfer. This empirical evidence implies that environmental uncertainty has no effect on knowledge transfer in this study. This study considers that the dimension of protectiveness could lead to this solution. This last result concurs with Simonin (2004), who shows that the more protective a partner is of its knowledge, dose not necessarily indicate a greater degree of knowledge ambiguity.

Fourthly, the main theoretical contribution of this study to the knowledge management is its re-conceptualization of environmental uncertainty. Traditionally, the concept of environmental uncertainty was been applied in the arena of economic and operation management. However, by re-conceptualizing this concept this study applies this variable in the field of knowledge management to describe the gap of knowledge provider and receivers when they exchange knowledge. Moreover, in the literature, ambiguity is similar to this concept, which result in knowledge attribute then cause the knowledge transfer unsmoothly (Simonin, 1999). Simonin's Research (1999, 2004) finds that partner protectiveness has a negative effect on knowledge transfer, although Simonin did not prove this relationship. However, this study proposes and explores how this factor could hinder knowledge transfer.

Finally, this study first considers environmental uncertainty as a manipulative variable. In the prior studies, Simonin (1999) examines the role played by the "causally ambiguous" nature of knowledge in the process of knowledge transfer. Jensen and Szulanski (2004) explore how the adaptation of organizational practices affects the stickiness of cross-border transfer, considering that ambiguity is neither a mediator nor an independent variable. Therefore, this study first considers environmental uncertainty as an input variable to investigate the influence on knowledge transfer and competitive advantage.

5.2. Future works

The study proposes several future works. First, although knowledge transfer in organizations was highlighted on R&D and technology management issues, strategy and marketing are also important sources for competitive advantage. Further study could include other knowledge sources to test their possible effects on competitive advantage. In addition, this paper does not constrain to any governance mechanism when organizations share their knowledge with others, such as strategy alliances or joint venture. Further research may consider any governance mechanism to examine our finding in this study. Secondly, more subjects from different department could be considered in a future study in order to reduce the limitations of research samples and enlarge the scope of knowledge management activities of firms. Thirdly, more control variables could investigate different results on this issue in the future. Generally speaking, the proposed framework may benefit from control variables as prior experience (Simonin, 1999), relationship (Sakakibara, 1997), organization distance (Simonin, 1999), and location (Minbaeva et al., 2003). Degrees of freedom were not available to include all control variables in this study. Therefore, this study suggests that future study can implement different control variables.

Overall, the research limitations of this study are the personal and objective aspects, so it is not possible to use better statistical sampling methods (for example, stratified random sampling) to select the samples. Prior study (Hsieh et al., 2006) also used 2002 Semiconductor Annual Databook as their sampling frame. Due to the small population, no sampling was carried out. First, each subject was contacted by telephone to solicit cooperation in the study, then surveys were finally sent by mail and, additionally, by e-mail. A week after distribution of the mailed survey, reminder phone calls were made to each targeted manager to verify receipt and to promote return of the surveys (Hsieh et al., 2006). Therefore, only the convenience sampling method was used to select the investigation targets of this research, and so errors from real situation to the sampling results may be unavoidable. Also, the results from this research might not apply to other areas or industries due to differences in the culture, internal industry environment and characteristics. Though, we have found some similar result in literature. Yli-Renko et al. (2001) indicated that entrepreneurs may be able to actively manage their firm's social capital to stimulate knowledge acquisition and build competitive advantage in 180 young technology-based firms in the United Kingdom. Moreover,

De Carolis (2003) found that in technologically dynamic industries, the acquisition and incorporation of new knowledge is critical to both short- and long-term competitive advantage in the pharmaceutical industry. However, if we want to justify our model can be generalized to other countries, industries, and culture, multi-group structural equation modeling to testified validity generalization (Diamantopoulos and Siguaw, 2000) probably provides a better approach.

6. Conclusion

This study investigates the inter-relationships among environmental uncertainty, knowledge transfer, and competitive advantage. Based on 176 research samples from the Taiwan semiconductor industry, this study implements the structural equation model to test research framework and hypotheses. Thus, this paper finds that knowledge transfer could develop organizations' core competence and then build their own competitive advantage. Therefore, knowledge transfer to firms is a very important activity in a rapidly changing industry environment. In addition, this study considers that environmental uncertainty is a vital factor during knowledge transfer. Previous studies on environmental uncertainty, such as Simonin (1999, 2004), Szulanski et al. (2004), all argue that ambiguity could hinder the smoothness of knowledge transfer. However, according to the empirical findings of this study, the relationship among environmental uncertainty, knowledge transfer, and competitive advantage is insignificant. This article also considers that environmental uncertainty is an important variable that has an effect on knowledge transfer and can hinder an organization from acquiring sustained competitive advantage. Accordingly, this study suggests that further research could focus on the development of environmental uncertainty factors and consider different knowledge management activities in order to investigate its possible influence.

References

Allen, T.J., 1977. Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information Within the R&D Organization. MIT Press, Cambridge, MA.

Almeida, P., Kogut, B., 1999. Localization of knowledge and the mobility of engineers in regional networks. Management Science 45 (7), 905–917.

Anderson, J.C., Gerbing, D.W., 1988. Structure equation model in practice: a review and recommended two-step approach. Psychological Bulletin 103 (3), 411–423.

Argote, L., Ingram, P., 2000. Knowledge transfer: a basis for competitive advantage in firms. Organizational Behavior and Human Decision Processes 82 (1), 150–169.

Bagozzi, R., Phillips, L., 1982. Representing and testing organizational theories: a holistic construal. Administrative Science Quarterly 27, 459–489.

Bagozzi, R., Yi, Y., 1988. On the evaluation of structural equation models. Journal of the Academy of Marketing Science 16, 77–94.

Bapuji, H., Crossan, M., 2004. From questions to answers: reviewing organizational learning research. Management Learning 35 (4), 397–417.

Barney, J.B., 1991. Firm resources and sustained competitive advantage. Journal of Management 17, 99–120.

Baum, J.A.C., Ingram, P., 1998. Survival-enhancing learning in the Manhattan hotel industry 1898–1980. Management Science 44 (7), 996–1016.

Bentler, P.M., 1990. Significance tests and goodness of fit in the analysis of covariance structures. Psychological Bulletin 88, 588–606.

Berry, D.C., Broadbent, D.E., 1984. On the relationship between task performance and associated verbalizable knowledge. The Quarterly Journal of Experimental Psychology 36A, 209–231.

Berry, D.C., Broadbent, D.E., 1987. The combination of explicit and implicit learning processes in task control. Psychological Research 49, 7–15.

Bjorkman, I., Barner-Rasmussen, W., Li, L., 2004. Managing knowledge transfer in MNCs: the impact of headquarters control mechanisms. Journal of International Business Studies 35 (5), 443–455.

Burt, R.L., 1992. Structural Holes. Harvard University Press, Cambridge, MA.

Cavusgil, S.T., Calantone, R.J., Zhao, Y., 2003. Tacit knowledge transfer and firm innovation capability. Journal of Business & Industrial Marketing 18 (1), 6–21.

Chang, P.L., Shin, C., Hsu, C.W., 1994. The formation process of Taiwan's IC industry—method of technology transfer. Technovation 14 (3), 161–171.

Chen, C., Lin, B., 2004. The effects of environment, knowledge attribute, organizational climate, and firm characteristics on knowledge sourcing decisions. R&D Management 34 (2), 137–146.

Cheng, S.C., 2003. Exploration of knowledge competitive capability-the case of Taiwan IC design Industry. Unpublished Master Thesis, National Defense Management College, Taipei, Taiwan.

Cheng, J.W., Li, S.C., 2001. The relationships of organization justice, trust and knowledge sharing behaviors. Journal of Human Management (Taiwan) 1 (2), 69–93.

Cohen, W., Levinthal, D., 1990. Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly 35, 128–152.

Cummings, J.N., 2004. Work groups, structural diversity and knowledge sharing in a global organization. Management Science 50 (3), 352–364.

De Carolis, D.M., 2003. Competencies and imitability in the pharmaceutical industry: an analysis of their relationship with firm performance. Journal of Management 29 (1), 27–50.

Dhanaraj, C., Lyles, M.A., Steensma, H.K., Tihanyi, L., 2004. Managing tacit and explicit knowledge transfer in IJVs: the role of relational embeddedness and the impact on performance. Journal of International Business Studies 35 (5), 428–442.

Diamantopoulos, A., Siguaw, J.A., 2000. Introducing LISREL: A Guild for Uninitiated. Sage, Thousand Oaks, CA.

Fornell, C., 1982. A second generation of multivariate analysis: an overview. In: Fornell, C. (Ed.), A Second Generation of Multivariate Analysis: Methods. Praeger, New York, pp. 407–450.

Galbraith, C.S., 1990. Transferring core manufacturing technologies in high technology firms. California Management Review 32 (4), 56–70.

Heiman, B.A., Nickerson, J.A., 2004. Empirical evidence regarding the tension between knowledge sharing and knowledge expropriation in collaborations. Managerial and Decision Economics 25, 401–420.

Hsieh, M.H., Tsai, K.H., Hultink, E.J., 2006. The relationships between resource configurations and launch strategies in Taiwan's IC design industry: an exploratory study. Journal of Production Innovation Management 23, 259–273.

ITRI, 1999–2001. Year Books of Semiconductor Industry. MOEA, Taiwan.

Jensen, R., Szulanski, G., 2004. Stickiness and the adaptation of organizational practices in cross-border knowledge transfers. Journal of International Business Studies 35 (6), 508–523.

Joreskog, K.G., Sorbom, D., 1996. LISREL VIII. SPSS, Chicago, IL.

King, A.W., Zeithaml, 2001. Competencies and firm performance: examining the causal ambiguity paradox. Strategic Management Journal 22 (1), 75–99.

Kogut, B., Zander, U., 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. Organization Science 3 (3), 383–397.

Lambe, C.J., Spekman, R.E., 1997. Alliances, external technology acquisition, and discontinuous technological change. Journal of Production Innovation Management 14, 102–116.

Lin, B.W., 2003. Technology transfer as technological learning: a source of competitive advantage for firms with limited R&D resources. R&D Management 33 (3), 327–341.

Lippman, S., Rumelt, R., 1982. Uncertain imitability: an analysis of interfirm differences in efficiency under competition. Bell Journal of Economics 13 (2), 418–438.

Lyles, M., Salk, J., 1996. Knowledge acquisition from foreign parents in international joint ventures: an empirical examination in the Hungarian context. Journal of International Business Studies 27 (5), 877–903.

Mansfield, E., 1968. The Economics of Technological Change. W.W. Norton, New York.

Minbaeva, D., 2005. HRM practices and MNC knowledge transfer. Personnel Review 34 (1), 125–144.

Minbaeva, D., Pedersen, T., Bjorkman, I., Fey, C.F., Park, H.J., 2003. MNC knowledge transfer, subsidiary absorptive capacity and HRM. Journal of International Business Studies 34, 586–599.

Nahapiet, J., Ghoshal, S., 1998. Social capital, intellectual capital and the organizational advantage. Academy of Management Review 23, 242–266.

Nakamura, A., Nakamura, M., 2004. Firm performance, knowledge transfer and international joint ventures [1]. International Journal of Technology Management 27 (8), 731–746.

Nonaka, I., Takeuchi, H., 1995. The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation. Oxford University Press, Oxford.

Nunnally, J.C., 1978. Psychometric Theory, second ed. McGraw-Hall, New York.

Phan, P.H., Peridis, T., 2000. Knowledge creation in strategic alliances: another look at organizational learning. Asia Pacific Journal of Management 17 (2), 201–222.

Polanyi, M., 1967. The Tacit Dimension. Dubleday, New York.

Pramongkit, P., Shawyun, T., Sirinaovakul, B., 2000. "Analysis of technological learning for the Thai manufacturing industry. Technovation 20, 189–195.

Reed, R., DeFillippi, R.J., 1990. Causal ambiguity, barriers to imitation, and sustainable competitive advantage. Academy of Management Review 15 (1), 88–102.

Sakakibara, M., 1997. Heterogeneity of firm capabilities and cooperative research and development: an empirical examination of motives. Strategic Management Journal 18 (Summer Special Issue), 143–164.

Simonin, B.L., 1999. Ambiguity and the process of knowledge transfer in strategic alliances. Strategic Management Journal 20 (7), 595–623.

Simonin, B.L., 2004. An empirical investigation of the process of knowledge transfer in international strategic alliances. Journal of International Business Studies 35 (5), 407–427.

Syed-Lkhsan, S.O.S., Rowland, F., 2004. Knowledge management in a public organization: a study on the relationship between organizational elements and the performance of knowledge transfer. Journal of knowledge management 8 (2), 95–111.

Szulanski, G., 1996. Exploring internal stickiness: impediments to the transfer of best practice within the firm. Strategic Management Journal 17 (Winter Special Issue), 27–43.

Szulanski, G., 2000. The process of knowledge transfer: a diachronic analysis of stickiness. Organization Behavior and Human Decision Processes 82 (1), 9–27.

Szulanski, G., Cappetta, R., Jensen, R.J., 2004. When and how trustworthiness matters: knowledge transfer and the moderating effect of causal ambiguity. Organization Science 15 (5), 600–613.

von Hippel, E., 1994. Sticky information and the locus of problem solving: implications for innovation. Management Science 40 (4), 429–439.

Walsh, S., Kirchhoff, B., 2002. Entrepreneurs' opportunities in technology-based markets, vol. 2, June, Research in Entrepreneurship and Management.

Wang, P., Tong, T.W., Koh, C.P., 2004. An integrated model of knowledge transfer from MNC parent to China subsidiary. Journal of World Business 39, 168–182.

Yang, C.C., 2000. A study of Interaction model in technology process: the case of cooperation between R&D institutions and small businesses in Taiwan. Unpublished Doctoral Dissertation, National Taiwan University, Taipei, Taiwan.

Yli-Renko, H., Autio, E., Sapienza, H.J., 2001. Social capital, knowledge acquisition, and knowledge exploitation in young technology-based firms. Strategic Management Journal 22, 587–613.

Zack, H., 1999. Managing codified knowledge. Sloan Management Review 40 (4), 45–58.

Zander, U., 1991. Exploiting a Technological Edge: Voluntary and Involuntary Dissemination of Technology. Institute of International Business, Stockholm.

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