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Technological and design capabilities: is ambidexterity possible?

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Abstract

Purpose – This study seeks to employ the capability-based view to investigate the direct effect of an organization's development of technological and design capabilities on technology commercialization. It aims to use two indicators to test the claim of ambidexterity, i.e. that synchronizing the development of technological capabilities and design capabilities can enhance the performance of technology commercialization.

Design/methodology/approach – The research subjects consisted of R&D teams in Taiwan developing new high-tech information and communications products; a total of 109 valid questionnaires were recovered. A hierarchical multiple regression model was used to perform hypothesis testing.

Findings – The findings of this study indicate that both technological and design capabilities have a positive effect on technology commercialization results, and the contribution of design capabilities is greater than that of technological capabilities. The interaction of technological capabilities and design capabilities has a positive influence on the results of technology commercialization. A relative imbalance between technological and design capabilities has a negative effect on technology commercialization.

Originality/value – This study specifies that there are tensions between technological and design capabilities. However, an ambidextrous strategy involving the concurrent development of technological and design capabilities is suggested. Also the ambidexterity hypothesis is verified. This study consequently suggests that enterprises should simultaneously develop their technological and design capabilities, and seek to balance the allocation of management attention and resources between these two types of capabilities, if they wish to obtain optimal technology commercialization results.

Keywords Design, Research and development

Paper type Research paper

Introduction

Technology commercialization (TC) is an important driver of a firm's success (Cohen and Levinthal, 1990; Eisenhardt and Martin, 2000; Li *et al.*, 2008; Zahra and Nielsen, 2002). Many capabilities are needed to achieve the successful commercialization of technology (Zahra *et al.*, 2007), such as excellent embedded technological capabilities and design capabilities that can attract customers through product appearance, effective functions, and high quality. From a capability-based view, regardless of whether an enterprise possesses technological capabilities or design capabilities, both will have positive effects on TC results. Over the past 20 years, Taiwan's ICT firms have continuously developed

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and improved their technological capabilities in line with an OEM business model, and have successfully obtained TC and established a competitive advantage. But as technology advances at a breakneck pace and global markets become the norm, the OBM business model demands that managers opt for synchronized development of technological capabilities and product design capabilities.

Because the development of technological and design capabilities require different resources, abilities, and procedures, the basic logics of the two types of capabilities are different and somewhat distinct (Christensen, 1995; Rindova and Petkova, 2007). As a consequence, a firm's choice of developing either technological and design capabilities, or engaging in the synchronized development of both, will also affect the firm's allocation of organizational resources and investment strategies. The concurrent development of two types of capabilities will cause the two capabilities to compete for the organization's scare resources. This will cause tension and force the organization to choose between the two types of strategy. In addition, due to organizational inertia, a manager tends to develop a certain existing capability in which the firm already possesses expertise, which in the long-term causes the firm to neglect, and to lack the ability, to develop another capability (March, 1991; Levinthal and March, 1993). These accounts suggest that there is a trade-off relationship between the development of technological and design capabilities, and that it is extremely difficult for organizations to manage the development of these two types of capabilities at the same time.

But as technology has continued to advance and competition has become ever more intense, the successful TC results no longer rely solely on either one type of capability. Good design and good technology are similarly important in the successful achievement of TC, and design capabilities can be used to promote the expression of basic technology (Roy and Riedel, 1997). For instance, Lojacono and Zaccai (2004) and Ravasi and Lojacono (2005) suggested that product design can improve the process of technology search and innovation, as in the case of updating strategies, and design can consequently be used to encourage technological innovation and provide new developmental directions (Rindova and Petkova, 2007). The empirical findings of Nobel (1995), Jayaram and Narasimhan (2007), and Jang *et al.* (2009) support this view. The concurrent development of both types of capabilities is often viewed as an ambidextrous strategy. As we know that the concept of ambidexterity means an organization's ability to simultaneously perform differing and often competing, strategic acts (Simsek *et al.*, 2009). The literature on ambidexterity also emphasize that the tension between two distinct capabilities is a key strategic challenge for creating a sustained competitive advantage (Raisch and Birkinshaw, 2008).

Overall, building on the organizational ambidexterity literature (He and Wong, 2004; Sarkees and Hulland, 2009; Tushman and O'Reilly, 1996), this study suggests that there are tensions between technological and design capabilities, but dual focus and balancing the contradictory tensions are important. Enterprise managers should therefore try to strike an effective balance between technological and design capabilities if they wish to enhance the value of new products and achieve successful TC.

Although the benefits of an ambidextrous strategy calling for the concurrent development of two types of capabilities have been mentioned on numerous occasions, little direct empirical research has been performed on the subject. This is the principal research goal and contribution of this study. According to the capability-based view, this study first examines the direct effect of the development of technological and

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design capabilities by ICT firms in Taiwan on TC. In addition, two indicators are used to test ambidexterity – the effect of the synchronized development of technological and design capabilities on TC: the first indicator is the interaction, and the second is the relative imbalance between the two types of capabilities. Finally, this study discusses the empirical results and provides recommendations.

Literature review and hypotheses

The capability-based view

Scholars proposing the capability-based view (CBV), such as Prahalad and Hamel (1990), define capabilities as "the cumulative results of an organization's overall learning, particularly learning how to coordinate production technologies dispersed throughout different locations and how to integrate diverse technologies; capabilities involve an organization's operating systems and delivery of values". Subsequent scholars (Schreyogg and Kliesch-Eberl, 2007; Teece *et al.*, 1997; Winter, 2000) have suggested that capabilities are the results of collective learning processes, combination of unique technologies and skills, and are embedded in the organization and its procedures. Because of this, it can be said that capabilities represent a firm's ability to deploy its resources so as to achieve specific results.

Owing to the turbulence of environment in recent years, some scholars (Teece *et al.*, 1997; Kusunoki *et al.*, 1998; Eisenhardt and Martin, 2000; Zollo and Winter, 2002; Winter, 2003) have begun to focus on a dynamic capability view, which is concerned with how an organization can gain the ability to change and rapidly develop new organizational capabilities. Research on dynamic capabilities emphasizes an organization's ability to integrate, reconfigure, acquire, and release resources so as to adapt to changes in markets (Eisenhardt and Martin, 2000; Henderson and Cockburn, 1994; Teece *et al.*, 1997). Not only are markets dynamic, capabilities are themselves dynamic and flexible (Helfat and Peteraf, 2003). Eisenhardt and Martin (2000) further suggest that the development of dynamic capabilities emphasizes manipulation of resources. An unique and better method to deploy and integrate resources is the key to achievement of optimal performance (Schreyogg and Kliesch-Eberl, 2007).

The majority of studies (Dougherty and Hardy, 1996; McGrath *et al.*, 1996; Pennings and Harianto, 1992; Teece, 1986; Teece *et al.*, 1997; Schreyogg and Kliesch-Eberl, 2007) agree that the development of capabilities can establish or strengthen an enterprise's competitive advantage in a turbulent environment. For example, successful TC can enable a firm to obtain competitive advantage (Cooper, 2000; Zahra and Nielsen, 2002). TC can also be seen as the result created by organizational capabilities (Teece *et al.*, 1997). This study therefore employs the capability-based view to investigate the effect of, and the degree to which, an organization develops its technological and design capabilities on TC.

In addition, in view of the time needed to develop capabilities and the fact that the results of the learning process are highly idiosyncratic, a manager must decide which capabilities to develop and invest in, and establish a strategy for this purpose (Schreyogg and Kliesch-Eberl, 2007). As a consequence, the management decisions of what capability to develop, or which different capabilities to develop concurrently, are also strategy decisions. This study also employs the capability-based view to explain the trade-off relationships between technological and design capabilities, and the effect of the relationship on TC results, and thereby propose hypotheses.

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The direct effects of technological and design capabilities on TC

Successful TC implies that the organization can satisfy customer needs with respect to cost, speed, quality, and newness (Zahra and Nielsen, 2002). Mitchell and Singh (1996, p. 170) define TC as "the process of acquiring ideas, augmenting them with complementary knowledge, developing and manufacturing saleable goods, and selling the goods in a market". Zahra and Neilsen divide TC into four aspects:

(1) frequency of introduction of new products;

(2) introduction of new products faster than competitors;

(3) ability to create highly innovative new products; and

(4) knowledge created by the organization as indicated by new patents.

Scholars of strategic management (like Dougherty and Hardy, 1996; McGrath *et al.*, 1996; Pennings and Harianto, 1992; Teece *et al.*, 1997) have suggested that robust and diversified capabilities are required in order to achieve TC, particularly technological capabilities (Ettlie, 1997; Prasnikar *et al.*, 2008; Siegel *et al.*, 1995; Zahra and Nielsen, 2002) and design capabilities (Candi and Saemundsson, 2008; Dell'Era and Verganti, 2009; Gemser *et al.*, 2006; Rindova and Petkova, 2007; Veryzer, 2005).

According to Zahra and Nielsen (2002), "Technological capabilities are the set of skills the firm has in building and leveraging different technologies and systems". Technological capabilities are multifaceted (Zahra *et al.*, 2007) and include R&D, manufacturing, and integrated capabilities, etc. A firm possessing R&D technological capabilities can build on the technology it has experience in and establish new technologies or improve R&D functions (Song *et al.*, 2005). Manufacturing technological capabilities can determine whether a firm can transform successful R&D results into products, and improve product quality (Wang *et al.*, 2008). In addition, an internal/external and new/old knowledge integration capability is a critical element ensuring robust technological capabilities (Isobe *et al.*, 2008; Lichtenthaler and Ernst, 2009).

The assumption that effective technological capabilities can facilitate new product development and successful achievement of TC is well-verified (Burgelman *et al.*, 2004; Day, 1994; Song *et al.*, 2005; Stalk *et al.*, 1992; Tsai, 2004; Wang *et al.*, 2008; Zahra *et al.*, 2007). Taiwan's high-tech firms have developed low-cost, high-efficiency manufacturing technologies in line with their specialized OEM business models. As a result, these high-tech firms' manufacturing technological capabilities indeed facilitate the firms' new product introduction speed and frequency. The stronger the firms' manufacturing technological capabilities are, the greater their abilities of developing R&D technological capabilities will be. Raising the technological threshold also has a positive effect on TC results such as level of innovation and number of new patents. In addition, tech firms in Taiwan commonly use such methods as strategic alliances and even acquisitions to increase their new technological capabilities. This study therefore proposes that strong technological capabilities can promote increased new product commercialization frequency and speed, degree of innovation, and even number of patents. Thus:

H1. The strength of technological capabilities will be positively associated with the results of TC.

Compared with technological capabilities, there is relatively little literature concerning design capabilities. But as global market competition becomes increasingly fierce, both

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academic researchers and practical workers universally believe that strong design capabilities can improve product value, especially in the case of high-tech products (Candi, 2006). As a result, there has been growing attention to and discussion of design capabilities in recent years. Based on the capability-based view and the studies of Cagan and Vogel (2002), Rindova and Petkova (2007), Swan *et al.* (2005), Ulrich and Eppinger (2004), Veryzer (2005), this study defines design capabilities as the resources that an organization devotes to manpower, methods, knowledge, processes, systems, and equipment, where the results of deploying these resources can promote interaction between products and users, enhance basic technical performance, imbue products with new functions, reliability, quality, or ease of use, or develop external designs able to attract customers.

According to the foregoing definition, design capabilities include function, compatibility, appearance, and quality capabilities. Function design capabilities emphasize the importance of utility; effective design can make a product less expensive and easier to use (Veryzer, 2005), which will promote the efficiency of TC. Compatibility design capabilities refer to an organization's ability to design new products that are compatible with existing products; such products will be better trusted by the market, and readily accepted by consumers (Rindova and Petkova, 2007), thereby facilitating the efficiency of TC. Appearance (or aesthetic) design can facilitate communication between a product and consumers, and is an important method of differentiation (Bloch, 1995). The ability to design products with an attractive appearance can facilitate innovative TC results (Candi, 2006; Ulrich and Eppinger, 2004). Quality design capabilities refer to an organization's ability to design products that are reliable and possess stable quality. Because quality design capabilities can extend the service life of product and reduce defects (Swan *et al.*, 2005), they can also facilitate more efficient TC.

Consequently, based on the inevitable relationship between capabilities and performance proposed in the capability-based view (Schreyogg and Kliesch-Eberl, 2007) and the foregoing discussion, this study proposes that strong design capabilities can promote successful TC, including new product commercialization frequency and speed, degree of innovation, and even number of patents. Therefore:

H2. The strength of design capabilities will be positively associated with the results of TC.

Relationship between technological capabilities and design capabilities

According to the capability-based view, capabilities consist of combinations of "diverse and mutually-interconnected" assets, and unique technologies and skills, which are embedded in the organization and procedures, and can strengthen a firm's resource productivity. Capabilities must be established, and cannot necessarily be acquired by purchase (Schreyogg and Kliesch-Eberl, 2007; Teece *et al.*, 1997; Winter, 2000). As a consequence, the development of either technological capabilities or design capabilities requires input of time and resources from the organization. This implies that the decision to develop either type of capability, or to simultaneously develop both types of capabilities, is a strategic decision (Bitar and Hafsi, 2007). From the point of view of a manager, whether or not opting to develop one of the two types of capabilities, or adopting an ambidextrous strategy, will yield optimally competitive TC results requires investigation of the relationship between the two types of capabilities.

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This study proposes that there is a trade-off relationship between the two types of capabilities for three reasons. First, the basic logic of technological and design capabilities are different and somewhat distinct (Rindova and Petkova, 2007). When selecting a strategy, firms are primarily concerned about how much investment different types of activities will require. The two types of capabilities will accordingly compete for an organization's limited resources, and which tends to force organizations to choose to develop one of the two capabilities. Second, organizational inertia has a tendency to cause an organization to continue to commit itself to a certain type of capability (Sarkees and Hulland, 2009). Because of this, as far as an organization is concerned, even if the external environment changes, the preferred strategy is still to maintain and strengthen its existing, strongest capabilities, and give up the development of the other kind of capability. This move will cause core capabilities to be turned into core rigidities, however (Leonard-Barton, 1995). Third, the successful TC results, for the most part, depend on a firm's capacity of R&D department. Developing technological and design capabilities simultaneously within the same unit not only involves scarcity of resources, but also a challenge to organizational routines. For example, the success of the OEM and ODM models for Taiwan's ICT firms enabled them to develop robust, outstanding technological capabilities. However, when the market environment changed, exploiting an existing capability such as technological capability is not enough to help these firms achieve better TC results, so exploring new ones such as design capability is also needed. Owing to the limited resources, attention and the path-dependence of existing capability, managers of R&D department may tend to reinforce existing patterns of developing activities and resist changing. Thus, there are inherent tensions between technological and design capabilities that is indicated.

Nevertheless, scholars have proposed that good design and good technology are similarly important in the successful achievement of TC. For its part, design can improve performance (Candi, 2006; Walsh *et al.*, 1992) and help firms better understand the needs of their customers (Verganti, 2008). In particular, in markets where technology is becoming increasingly mature, design can increase the value of a product for customers (Walsh, 1996; Rothwell and Gardiner, 1989). Also design capabilities can be used to express basic technologies (Roy and Riedel, 1997). Empirical support for this argument can be found in the literature; for instance, Lojacono and Zaccai (2004) suggests that product design capabilities can improve the process of technology search and innovation, as in the case of strategic renewal. Jayaram and Narasimhan (2007) support the assumption that the concurrent possession of several types of competitive capabilities will achieve a synergistic effect, which can promote the successful development of new products. Swink and Nair (2007) suggest that design and manufacturing are potentially important complementary assets, and propose that the interaction between the two factors can yield a competitive advantage. Jang *et al.* (2009) took LG Electronics' Chocolate Phone as an example, and proposed that strong technological capabilities and optimized design functions are keys to successful new products.

Owing to the trade-off relationship between technologic and design capabilities, there are tensions existing at ICT firms especially in R&D department. However, for the accelerating technology development and intense competing global market, dual focus and balancing the contradictory tensions are important. Enterprise managers should therefore try to strike an effective balance between technological and design capabilities if they wish to enhance the value of new products and achieve successful TC. The

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concurrent development of two capabilities fit well with the concept of ambidexterity. In general, the simultaneous pursuit of two types of disparate things by an organization has been termed an ambidextrous strategy (Adler *et al.*, 1999; Benner and Tushman, 2003; Gibson and Birkinshaw, 2004; Gupta *et al.*, 2006; He and Wong, 2004; Sarkees and Hulland, 2009). This study employs this term, and defines ambidexterity as: a firm that employs an ambidextrous strategy simultaneously engages in a high degree of both technological and design capabilities relative to its competitors.

Based on this definition of ambidexterity, this study proposes that the successful achievement of TC requires that product design be employed to realize embedded technological capabilities. This study therefore concludes that firms should adopt an ambidextrous strategy and synchronize their development of technological and design capabilities in order to boost TC results, create new value, and achieve an optimal competitive advantage.

With regard to the ambidexterity hypothesis, He and Wong (2004) was the first formal empirical study in the context of technological innovation strategies (Raisch and Birkinshaw, 2008). Their evidence showed that:

- the interaction between exploitative and explorative innovation strategies is positively related to sales growth rate; and
- the relative imbalance between exploitative and explorative innovation strategies is negatively related to sales growth rate.

Although there is no widely accepted measure of an ambidextrous strategy, He and Wong (2004) provided a sound basis to test for ambidexterity. Guided by design of ambidexterity hypothesis of He and Wong (2004), this study tests an ambidextrous strategy of concurrent development of technological and design capabilities as yjr following two dimensions:

(1) *The interaction term of technological and design capabilities* – when a firm has high scores for both technological and design capabilities, this implies that the firm simultaneously emphasizes the development of both types of capabilities. If a positive relationship between the interaction of two types of capabilities and TC, then the "fit as moderating" test of strategic fit (Venkatraman, 1989) can be applied. Technological and design capabilities will have a mutually synergistic effect, and will enhance TC results.

(2) *The absolute difference between technological and design capability scores* – this term means a firm relatively equal emphasis on both technological and design capabilities. Here the "fit as matching" test (Venkatraman, 1989) was adopted. This test concerned whether the match (a smaller absolute difference) between technological and design capabilities insofar as this can boost TC results.

Therefore, we hypothesize:

H3. The effect of interaction between technological and design capabilities on TC is positive.

H4. An imbalance between technological and design capabilities is negatively related to TC.

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Research design

Research framework

The relationship among the variables included in the hypothesis is presented in Figure 1.

Data source

This study first modified scales developed in extant literature to conform to its research goals. Ten project managers at ICT firms in Taiwan were selected as the subjects of the questionnaire pre-test. The recovered pre-test questionnaires were used to confirm the appropriateness of the wording and test reliability and validity; the formal questionnaire was compiled after deleting inappropriate items.

With regard to the formal sample, we used the Taiwan Association of Industries in Science Parks database to create a sample list; these lists was filtered by company business items, and firms not in the ICT firms or with no NPD experience were deleted. A total of 625 high-tech ICT firms meeting the study's criteria were selected. In order to boost the recovery rate, interviewers first confirmed the names and titles of R&D department executives or project managers by mail or telephone, and then sent questionnaires to those individuals. The formal questionnaire was issued in January and February of 2009. A total of 625 questionnaires were sent out by mail, of which 113 were recovered and 109 were valid, with a return rate of 18.1 percent.

Assessment of variables

The questionnaire variables in this study were chiefly developed from scales available in previous literature. Except for firm size, and number of persons in the R&D team, all questions were answered using a five-point Likert scale. The five questions on the TC scale were taken from the research of Nerkar and Shane (2007), Li *et al.* (2008), and Zahra and Nielsen (2002).

We ask respondents to state how firms divide attention and resources between technological and design developing activities in the last three years. The questionnaire contained 12 questions assessing technological capabilities, which were taken from the research of Danneels (2008), Isobe *et al.* (2008), Wang *et al.* (2008), Zhan and Luo (2008), and Zahra and Nielsen (2002). Design capabilities were measured by 16 questions, which were taken from Candi (2006), Jayaram and Narasimhan (2007), Rindova and Petkova (2007) and Swan *et al.* (2005).

This study controlled three other variables that might affect the model. These were size, NPD team size, and quadratic effects of technological and design capabilities.

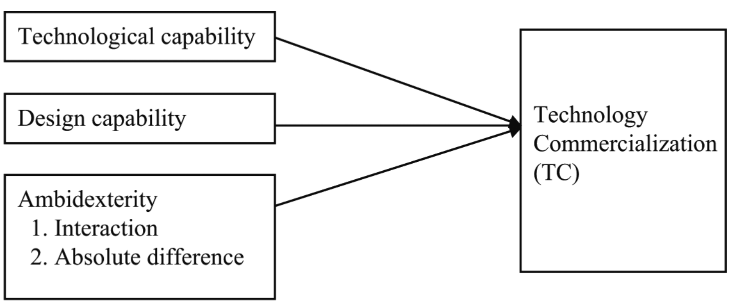

Figure 1.
Research framework

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According to the RBV, size will have a positive effect on TC performance, and was consequently taken as a control variable. Size was expressed in the model as the numbers of a firm's employees. Furthermore, because NPD team size express a firm's ability to acquire new knowledge and technology, and are associated with the firm's development of technological capability and design capability (Zahra *et al.*, 2007), these attributes were consequently also included among control variables. Finally, we also controlled the quadratic effects of technological capability and design capability on TC outcome to see if such effects are linear or curvilinear as technological capability and design capability continue to increase.

Analysis and results

There were 109 valid sample obtained from which we empirically analyze our model. The final sample consisted of new product projects in the following industries:

- semiconductors and IC design (24.7 percent);
- display-related products (12.4 percent);
- consumer electronics products and peripheries (18.6 percent);
- telecommunications equipment (16.5 percent);
- internet-related services and equipment (12.4 percent);
- phonics (3.1 percent); and
- software-related products (12.3 percent).

Reliability and validity

The descriptive statistics for the scales are summarized in Table I. The reliability of the measures exceeded 0.80 and met the standards for acceptance (see the Cronbach's α value in Table I).

Then, we used confirmatory factor analysis (CFA) to check the convergent validity (Bollen, 1989). The model fitness indices obtained from CFA are shown in Table II. With regard to technological capability and design capability aspects, apart from the slightly less than ideal value of the GFI, the other indicators all had good fitness.

Table I.
Means and standard deviations for all measures

Measures	Means	SD	Cronbach's α
Technological capability	3.6896	0.5971	0.893
Design capability	3.9037	0.5450	0.925
Technology commercialization	3.4202	0.7836	0.856

Table II.
Results of confirmatory factor analysis (CFA)

Dimensions	Items	Cronbach's α	χ^2/df	GFI	CFI	RMR
Technological capability	12	0.893	2.352	0.861	0.900	0.053
Design capability	16	0.925	2.298	0.828	0.927	0.031
TC	4	0.856	0.382	0.996	1.000	0.010
Critical value		>0.8	<3	>0.9	>0.9	<0.05

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Moreover, we used composite reliability (CR) and average variance extracted (AVE) (shown in Table III) to assess the model (Bagozzi and Yi, 1988). Table III shows that the factor loadings (λ) of the measured variables range from 0.428 to 0.832, only two values are under 0.5, the others are close to or greater than 0.5. The result indicates that this study has very good convergent validity. Furthermore, we found that the variables like "Continued implementation of practical R&D" ($\lambda = 0.805$) and "Good R&D of new product technology" ($\lambda = 0.803$) of technological capability have the highest loading factor values, while the variable "Good product manufacturing technology" ($\lambda = 0.428$) has the lowest loading factor value. As regards the variables of design capability, "Applies existing resources to design products that are compatible with existing products" ($\lambda = 0.819$), "Applies existing resources to design usable new products" ($\lambda = 0.817$), have the highest loading factor values, while "Has the ability to continuously improve existing products aesthetic design" ($\lambda = 0.496$) has the lowest loading factor value.

In addition, the AVE values are close to or greater than 0.5. The composite reliabilities (CR) values range from 0.826 to 0.974, which provides further proof of reliability in addition to the Cronbach's α values.

Regression results

Table IV shows the regression results for TC. Model 1 shows that both technological capability ($b = 0.426$, $p < 0.01$) and design capability ($b = 0.443$, $p < 0.001$) significantly and positively influence the TC result. Thus, *H1* and *H2* are therefore proven. Comparing the between the b values, design capability has a greater contribution than technological capability on successful TC results ($0.443 > 0.426$). Among the other control variables, R&D members and firm size appear not to influence TC result. The quadratic terms also are not statistically significant, suggesting that the positive impacts of these two capability variables on TC outcome do not decline with the incremental development of two capabilities.

Models 2 and 3 test ambidexterity *H3* and *H4*, respectively. Model 2 shows that the interaction effect between the two capabilities on TC results is positive and significant ($b = 0.473$, $p < 0.05$); this confirms *H3*. Model 3 shows that the absolute difference between the two capabilities is negatively related to TC results ($b = -0.213$, $p < 0.05$), while *H4* is supported. In addition, when we put the interaction and relative imbalance of two capabilities in to the Model 2 and Model 3, compared with Model 1, the contribution of technological capability on TC result was attenuated, especially technological capability becomes not significant in Model 3. But the contribution of design capability on TC results is still significant in Model 2 and Model 3.

Conclusions, discussion, and implications

The purpose of this study is to investigate the degree to which an organization's emphasis on and allocation of resources to technological and design capabilities influences TC. Also this study suggests that dual focus and balancing the contradictory tensions are important, although there are tensions between technological and design capabilities. Accordingly, the simultaneous development of two capabilities fit well with the concept of ambidexterity. Two methods are used to determine the effect of an ambidextrous strategy involving the concurrent development of technological and design capabilities on TC.

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Dimensions	Questions	λ	δ/ε	CR	AVE
Technological capabilities	Able to improve existing product technology	0.777	0.251	0.910	0.467
	Continuously improving production processes and quality	0.675	0.284		
	Continued implementation of practical R&D	0.805	0.199		
	Good R&D of new product technology	0.803	0.222		
	Good product manufacturing technology	0.428	0.691		
	Efficient product manufacturing	0.519	0.714		
	Ability to establish new manufacturing techniques and guidelines	0.584	0.469		
	Good integration of internal and external technologies	0.696	0.336		
	Regular assessment of the feasibility of new technologies	0.573	0.593		
	Regular learning of relevant technologies that were not used or fully utilized in the past	0.579	0.576		
	The firm will hire engineers in relevant fields when encountering unfamiliar technology	0.552	0.747		
	Regularly implements new types of manufacturing processes	0.600	0.588		
Design capabilities	Has the ability to continuously improve existing product functions	0.732	0.271	0.961	0.612
	Applies existing resources to design usable new products	0.817	0.170		
	Integrates internal and external resources in order to design usable new products	0.754	0.207		
	Seeks out new resources to design usable new products	0.787	0.227		
	Has the ability to continue to improve existing product designs, which facilitates compatibility with other products	0.773	0.240		
	Applies existing resources to design products that are compatible with existing products	0.819	0.183		
	Integrates internal and external resources to design products that are compatible with existing products	0.739	0.221		
	Seeks out new resources to design products that are compatible with existing products	0.594	0.315		
	Has the ability to continuously improve existing products aesthetic design	0.496	0.487		
	Applies existing resources to design new products with attractive aesthetics	0.501	0.468		
	Integrates internal and external resources to design new products with attractive aesthetics	0.512	0.482		
	Seeks out new resources to design new products with attractive aesthetics	0.509	0.463		
	Has the ability to continuously improve existing product quality, including product reliability and ease of use, etc.	0.621	0.276		
	Applies existing resources to design products with reliable quality and good ease of use	0.695	0.243		

(continued)

Table III.
Results of convergent validity, composite reliability and AVE

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Dimensions	Questions	λ	δ/ε	CR	AVE
	Integrates internal and external resources to design products with reliable quality and good ease of use	0.754	0.229		
	Seeks out new resources to design products with reliable quality and good ease of use	0.710	0.276		
Technology commercialization	R&D department (team) is able to quickly develop and commercialize new products	0.821	0.331	0.870	0.629
	R&D department (team) possesses many patents	0.658	0.550		
	R&D department (team) has introduced a large number of new products	0.832	0.235		
	R&D department (team) is able to develop new products with outstanding market potential	0.798	0.323		

Table III.

Variables	Technology commercialization Model 1	Model 2	Model 3
Control variables			
R&D team members	0.177	0.176	0.190^{*}
Firm size	-0.044	-0.027	-0.020
(Technological capability)^2	0.015	-0.217	-0.008
(Design capability)^2	0.007	-0.248	0.075
Independent variables			
Technological capability	0.426^{**}	0.304^{*}	0.303
Design capability	0.443^{**}	0.526^{**}	0.537^{**}
Interaction			
Technological capability $\times$ design capability		0.473^{*}	
Imbalance			
$\lvert$Technological capability $-$ design capability$\rvert$			-0.213^{*}
Maximum VIF	2.469	5.741	2.879
F-value	11.627^{***}	11.502^{***}	11.401^{***}
R^2	0.597	0.636	0.634
Adjusted R^2	0.546	0.581	0.579

Notes: $^{*}p \leq 0.05$; $^{**}p \leq 0.01$; $^{***}p \leq 0.001$

Table IV.
Results of regression

Empirical results indicate that, in the category of technological capabilities, Taiwan's ICT firms place greater emphasis on the development of their R&D technological capabilities, but devote relatively few resources to the development of manufacturing technological capabilities. With regard to design capabilities, such ICT firms generally emphasize improvement of compatibility and function capabilities, but commit fewer resources to the development of aesthetic design capabilities. This finding suggests that the deployment of resources at Taiwan's high-tech firms is gradually shifting from the development of manufacturing technological capabilities to the improvement of R&D technological capabilities. It should be noted that although Taiwan's ICT firms place

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roughly equal emphasis on, and devote equal resources to, technological and design capabilities, these firms tend to emphasize the design capability items of functions and compatibility, which have consistently been areas of strength for such firms. In contrast, these firms have placed relatively little emphasis on aesthetic capabilities, which has consistently been their area of weakness. As more and more firms shift from OEM to OBM strategies, however, and establish design centers, the development of aesthetic capabilities will be the key to success of the OBM model. It is consequently recommended that managers pursuing OBM strategies devote more resources to improvement of aesthetic capabilities when developing design capabilities.

Furthermore, empirical results indicate that while both technological and design capabilities have positive, significant effects on TC, the contribution of design capabilities is greater than that of technological capabilities. This conclusion is consistent with the capability-based view, which asserts that an organization's development of stronger technological and design capabilities will yield better TC results. As for the finding that design capabilities make a greater contribution to TC success than technological capabilities, this goes beyond the general perception of the current state of Taiwan's ICT industry. The reason for this finding may be that ICT markets have mostly entered a state of technological maturity, and emphasis on improvement of technological capabilities will therefore have little value-adding effect on TC (Tushman and O'Reilly, 1996). Under such circumstances, the strengthening of design capabilities will enhance the value of new products (Rothwell and Gardiner, 1989; Walsh, 1996). Because Taiwan's ICT firms are very conscious of market changes and trends, managers have begun to emphasize the development of design capabilities. ICT firms' allocation of resources to the development of design capabilities is verified by the contribution of such capabilities to successful TC. The success of Asus's Eee-PC and HTC's Touch-Diamond and Hero products shows that Taiwan's ICT firms are already reaping positive results from investment in design capabilities.

Moreover, the two hypotheses concerning ambidexterity are both proven. The positive relationship between the interaction of two types of capabilities and TC establishes the "fit as moderating" assumption. This finding indicates that the concurrent development of technological and design capabilities can achieve mutual synergy. The confirmation of the second hypothesis, that a relative imbalance (absolute difference) between technological and design capabilities is negatively associated with TC results, establishes the "fit as matching" assumption. These two findings indicate that there must be a balance between the two types of capabilities if a firm is to obtain optimal TC results. This study consequently provides direct empirical evidence that ICT firms in Taiwan pursuing an ambidextrous strategy involving simultaneous development of technological and design capabilities can achieve optimal TC results. These findings are consistent with the dominant point of view in the ambidexterity literature. Those tensions between technological and design capabilities were highlighted, but the importance of balancing seeming contradictory tensions was verified particularly. It is therefore recommended that managers place balanced emphasis on the two types of capabilities, and that enterprises simultaneously develop technological and design capabilities in order to achieve optimal TC results.

Finally, this study's contribution to management decision-making literature and practice lies in the following: the managers of Taiwan's ICT firms must have a clear awareness of the characteristics of their rapidly developing industries and the nature of

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intensely competitive global markets. In order to achieve successful TC and sustain competitive advantage, these managers must consider the option of an ambidextrous strategy involving synchronized technological and design capabilities. But when an ambidextrous strategy is adopted, interruption from organizational inertia and competition for resources between the two types of capabilities inevitably arise. In line with the suggestion proposed by Raisch *et al.* (2009), our finding indicates that managers must consequently manage the tension between technological and design capabilities, and allocate resources appropriately to the two capabilities, if they are to develop a synthesizing capability and achieve better TC than their competitors.

Limitations and suggestions

This study encountered some limitations that can only be overcome by further research:

- the study employed a cross-sectional research design, and longitudinal empirical data is needed to support a cause and effect relationship;
- since the study focused on high-tech ICT firms in Taiwan, it is difficult to generalize the results; and
- the study employed a questionnaire survey to collect data; since case managers filled out questionnaires themselves, there may have been a tendency for subjective views to bias.

This study has several recommendations concerning future research directions:

- The balance between technological and design capabilities may be connected with the magnitude of changes in markets and technology. Other scholars may therefore include environmental factors, controlled variables or moderating variables in a deeper investigation.
- Since an investigation of the development of capabilities ideally requires long-term data, scholars may collect longitudinal data and observations in a further investigation.
- The level of analysis of this study is at organizational level. However, ambidexterity may be held at individual level. Therefore, examining the individual dimension of ambidexterity is an intriguing avenue for future work.
- Scholars can perform in-depth research to discuss some other possible variables that an organization can design to achieve ambidexterity.

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