J. Eng. Technol. Manage. 27 (2010) 183–196

Contents lists available at ScienceDirect

Journal of Engineering and Technology Management

journal homepage: www.elsevier.com/locate/jengtecman

Can external corporate venturing broaden firm's technological scope? The role of complementary assets

Hsien-Che Lai [a,*], Yi-Chia Chiu [b], Yi-Ching Liaw [c]

[a] Department of Business & Management and Graduate Institute of Technology Management, National University of Tainan, No. 65, Yu-Nan Street, Tainan City 702, Taiwan

[b] Graduate Institute of Intellectual Property, National Chengchi University, No. 64, Sec. 2, Zhi Nan Road, Taipei City, Taiwan

[c] Graduate Institute of Business Administration, National Chung Hsing University, 3F, No. 19, Ln. 244, Fugang Street, Taipei City 111, Taiwan

ARTICLE INFO

Article history:
Available online 16 July 2010

JEL classification:
M13
O32
O31

Keywords:
External corporate venturing
Technological scope
Complementary assets
Resource-based view
Organizational learning
Electronics and information technology firms in Taiwan

ABSTRACT

This study applies two theoretical perspectives—resource-based view (RBV) and organizational learning—to explore how a firm's external corporate venturing (CV) influences its technological scope. Using data from 583 electronics and information technology firms in Taiwan for the period from 1997 to 2006, the results indicate that external CVs facilitate an established firm's broadening of its technological scope. Moreover, this study calls into question the idea that a firm's decisions regarding technological scope may be due to a specific factor that governs the extent of technological specialization and diversification. We identify this factor as the complementary assets of established firms. This study, thus, investigates whether complementary assets moderate the relationship between external CV in established firms and those firms' technological scope. The analytical results also support the idea that increasing investments in specialized complementary assets will urge firms engaged in external CV to concentrate on their technological scope. Therefore, this study addresses the notion that concentrated technological scope is the conjunction of technological capabilities and complementary assets, not determined by either individually.

* Corresponding author. Tel.: +886 6 2606123x7841; fax: +886 6 2606173.
E-mail address: hsienche@gmail.com (H.-C. Lai).

0923-4748/$ – see front matter
doi:10.1016/j.jengtecman.2010.06.005

1. Introduction

External corporate venturing (CV) is a vehicle that established firms can use to stimulate innovation (e.g., Birkinshaw and Hill, 2005; Dess et al., 2003; Weber and Weber, 2007), achieve competitive advantage and future growth (e.g., Schildt et al., 2005) by leveraging inter-organizational relationships to acquire, transfer, exploit and explore external resources from investments in corporate venture capital, joint ventures or acquisitions (e.g., Ireland et al., 2003; Keil, 2004). The specific means by which external CV can contribute to an established firm's success are many and varied (e.g., Schildt et al., 2005). External CV facilitates firms' construction of new capabilities that can extend the firm's reach into new opportunities previously outside the firm's operational scope. On the other hand, external CV also benefits firms in leveraging those capabilities that are strategically related to the firm's business (e.g., Schildt et al., 2005). External CV creates a platform for firms that execute the search for new and/or relevant capabilities. The above notion leads to the fundamental question: how does a firm's engagement in external CV determine the scope of its capabilities?

Prior studies on the topic of external CV have shown a positive relationship between external CV and established firms' innovativeness (e.g., Keil et al., 2008). Furthermore, previous studies have confirmed that external CV enables firms to monitor the development of technologies and markets (Keil, 2002), assimilate technologies previously used by their external partners (Schildt et al., 2005), develop new technological capabilities (e.g., Schoenmakers and Duysters, 2006), and react to technological change. These studies have added much to our understanding of the benefits of external CV in firm technological development. Despite a growing interest in the link between external CV and technological development, relatively little research explores how external CV influences firms' technological scope. Beyond the benefits of external CV in firm technological development, there is one critical decision that firms should pay attention to: whether to pursue an increasing number of firm-mastered technological capabilities that lead to technological diversification (e.g., Granstrand and Oskarsson, 1994; Suzuki and Kodama, 2004; Garcia-Vega, 2006; Wilbon, 1999) or to specialize in specific technological capabilities that are closely related to existing technological scope (e.g., Breschi and Malerba, 1999; Breschi et al., 2003). This question remains largely unanswered in the literature.

The present study, therefore, attempts to investigate how the external CV of established firms influences their technological scope by offering empirical evidence. Moreover, our argument highlights the role of external CV in inducing and cultivating organizational learning, which is a key source of new resources and knowledge that could be used to develop technological capabilities (e.g., Dess et al., 2003; Keil, 2004). In line with the above notion, this study employs two theoretical perspectives—the resource-based view (RBV) (e.g., Ireland et al., 2003; Keil, 2004) and organizational learning (e.g., Keil, 2004; Schildt et al., 2005)—to explore our research question. Answering this question can make a significant contribution to the literature on this topic.

Additionally, a firm's decision regarding technological scope may be influenced by several factors that govern the extent of technological specialization and diversification. This ambiguity implies that other factors may moderate the relationship between the external CV of established firms and their technological scope. Many empirical studies in CV literature have paid little attention to the above issue. We attempt to fill this gap by offering the notion of "complementary assets" (Teece, 1986), demonstrating that complementary assets are required in order for firms engaging in external CV to consider their technological scope.

Complementary assets are necessary when firms attempt to develop the new technologies necessary for a new product or market in a profitable manner (Teece, 1986; Christmann, 2000; Rothaermel and Hill, 2005; Colombo et al., 2006). In fact, firms possess distinctive technological capabilities relating to new products, processes or service ideas; these capabilities need to be used in conjunction with complementary assets in order to generate economic returns. Given that external CV is an effective vehicle for firm technological development, complementary assets are indeed necessary for profitability in deciding the extent of technological specialization and diversification. On the other hand, external CV has been regarded by prior studies inspired by RBV (e.g., Kogut, 1988) as an effective mechanism allowing the combination of the resource portfolio of an established firm with its new resources acquired by external partners so as to obtain synergistic gains (Colombo et al., 2006). However, one problem facing a firm is whether to exploit the resource commonalities and complementarities that exist among the complementary assets while investing in external CV to facilitate the coordination of its technology scope by creating synergy. The existing external CV literature on technological development neglects the significant role of complementary assets.

This study also aims to explore whether complementary assets moderate the relationship between the external CV of established firms and their technological scope. We advance research on complementary assets by empirically examining their effects on the use of external CV for the purpose of firms' technological development. The answer to the question of complementary assets is also important because such assets are relevant to firms that want to acquire technological capabilities by collaborating with different external partners.

The balance of this paper is organized as follows. The main hypotheses are proposed in Section 2. The methods, including measurements, sample, and regression analyses, are detailed in Section 3. Section 4 presents analytical results. Section 5 contains a discussion advancing the implications of this study. Finally, Sections 6 and 7 present concluding remarks and directions for future research, respectively.

2. Theoretical background and hypotheses development

In the following hypotheses, "technological scope" is defined as the extent to which a firm expands its technological capabilities from specific fields into a broader range of technological domains (Breschi et al., 2003; Garcia-Vega, 2006; Miller, 2006). "Technological specialization" is defined as the degree to which technology develops along specific directions that depend on a firm's existing technological fields. "Technological diversification" is defined as the degree to which technology spreads across technological fields (Breschi et al., 2003; Miller, 2006).

Consequently, the logic that directs technological specialization or diversification can be viewed as two ends of a continuum (see Breschi and Malerba, 1999). This study acknowledges the interdependence of technological specialization and diversification by conceptualizing these activities as residing along a single continuum rather than as two independent choices (e.g., Breschi and Malerba, 1999). This single continuum represents a firm's technological scope in this study.

On the other hand, a business requires investments that facilitate the growth of external businesses located outside a firm's established organizational boundaries; this process is called "external CV" (Covin and Miles, 2007) such as corporate venture capital, joint ventures or acquisitions (Keil, 2004). "Complementary assets" are defined as the resources required to capture the benefits associated with a technological development, including manufacturing, distribution, service and complementary technologies (Teece, 1986). This study applies two theoretical perspectives: RBV and organizational learning. By utilizing a full range of theoretical perspectives, this study can fully discover how external CV influences technological scope.

2.1. External corporate venturing and technological scope

2.1.1. Resource-based view

The early RBV literature (e.g., Barney, 1991) suggests that possessing valuable, rare, imperfectly imitable and non-substitutable (VRIN) resources provides the basis for creating competitive advantage and improvements in performance. Nevertheless, merely possessing such resources does not guarantee the development of competitive advantage or effective performance (Priem and Butler, 2001). For this to occur, firm resources must be properly exploited and managed (Peteraf, 1993). A great deal of theoretical work thus has suggested that resources within a firm's resource portfolio are integrated to create capabilities, with each capability a unique combination of resources allowing the firm to take specific action such as R&D and manufacturing. However, the key assumption of these studies was established by the pre-existence of resources within firms (Wang and Ahmed, 2007). The ways in which firms acquire new resources and develop new capabilities have recently attracted increasing RBV research interest (Helfat, 2000).

Opportunity- and growth-oriented firms often focus on expanding their businesses as quickly as possible to cope with a dynamic environment, although they may not possess all the necessary resources and capabilities. When the resources and capabilities cannot be effectively or efficiently developed internally, the firms in question often search for an external source. In particular, developing new technologies and products are usually done in a timely fashion. In practice, firms indeed acquire some resources beyond the firm's boundaries to overcome this problem. Technology-based firms often use external CV to acquire new resources possessed by other collaborative partners that are valuable and essential to building new technological capabilities and then achieving competitive advantage (e.g., Ireland et al., 2003; Zahra et al., 2009).

In line with the RBV, a firm can be regarded as a resource portfolio. The resources necessary for identifying and exploiting technological opportunities demand different sets of technological knowledge and capabilities to perform R&D tasks. However, the firm's resource portfolio can be shaped over time through managerial decisions or changing environments (Ireland et al., 2003). Continuous evaluation of the potential for existing resources to create synergy when combined with other resources in technology-based firms' resource portfolios is required. As technological opportunities vary over time, new resources for technological development may need to be added. External CV plays a role in supplementing the resource portfolios of technology-based firms by helping facilitate access to external resources. In the development of new technology, firms may seek unfamiliar technological know-how, new equipment, different configurations for R&D teams or other resources of their collaborative partners through external CV (Zahra et al., 2009). Resources residing outside the firm can contribute to triggering technological development.

Having new resources rarely allows a firm to develop a competitive advantage. However, acquiring new resources provides the foundation for developing new technological capabilities (e.g., Tyler, 2001; Morrow et al., 2007). Deciding which technological capabilities to build, how to build them and how to exploit these capabilities requires effective management. The following section further introduces the notion of organizational learning to discuss the development of new technological capabilities.

2.1.2. Organizational learning perspective

To develop new technological capabilities, firms usually need to gain access to different resources from external sources. Although it is difficult to create a competitive advantage based solely on individual resources from external sources, combining externally acquired resources with an existing resource portfolio held by a firm can create value that exceeds the value of individual resources (Ireland et al., 2003). Managers may revamp current technological capabilities by building new ones using the firm's internal and external resources as inputs into the development of these new technological capabilities (Zahra and George, 2002).

Knowledge is among the most valuable resources because it determines a firm's new product offerings, its ability to configure resources differently, and its ability to develop and implement technological development. Organizational learning is often understood as the process through which an organization acquires, processes and maintains, and then uses or exploits, new knowledge (Zahra et al., 1999). New knowledge and its use in the processes of the firm are thus an essential building block of new technological capabilities (Keil, 2004). Existing literature on new capability development often mentions organizational learning as an important process for capability-building (Teece et al., 1997).

Indeed, external CV can create significant opportunities for multifaceted organizational learning (Zahra et al., 1999). The role of external CV in the acquisition of new technological, social and organizational knowledge is well-recognized in previous studies (Ravasi and Turati, 2005). In external CV, the availability of multiple scientific areas of experience aids R&D professionals in developing new knowledge and expanding existing knowledge bases through the cross-fertilization of ideas (Quintana-Garcia and Benavides-Velasco, 2008). New technological knowledge often occurs through the process of specific functional collaboration with external partners. The above discussion leads to a question of whether firms apply this external knowledge to generate new technological capabilities (i.e., explorative learning) or enhance existing ones (i.e., exploitative learning).

Previous studies have suggested a good deal of evidence to address the idea that both explorative and exploitative learning are needed for the long-term survival of a firm (Schildt et al., 2005). But there is often tension between explorative and exploitative learning due to the firm's strategic posture or organizational context (Lavie and Rosenkopf, 2006). Many studies (e.g., Berends et al., 2007; Bierly et al., 2009) have confirmed that firms tend to apply external knowledge more through pursuit of explorative learning than exploitative learning. Compared with other firms, firms engaging in external CV that tends to play a greater role in generating new technological capabilities (i.e., explorative learning) than in enhancing existing capabilities (i.e., exploitative learning) (Keil, 2001). Although enhancing existing technological capabilities is essential to firms' prosperity, the exploration of new technological opportunities for established firms and experimentation with new external knowledge is central to external CV activity (Ravasi and Turati, 2005). External CV is also a strategic posture that will help established firms acquire external knowledge, expand their knowledge base, and provide access to more explorative learning that promotes the generation of new technological capabilities.

Explorative learning requires an extensive search and a departure from the established firm's store of current knowledge and skills (Quintana-Garcia and Benavides-Velasco, 2008); for instance, it might involve technological knowledge with which the firm has little previous experience. Explorative learning may also stimulate a firm's capacity to explore domains that are far from the existing technology domain of the firm. An established firm's exploration induced by external CV often combines its stock of knowledge with external knowledge, resulting in new technological capabilities. These new capabilities driven by explorative learning can drive a search for novel or complementary solutions by diversifying established firms' technology bases and leading to the capture of technological opportunities. Accordingly, explorative learning influences the rate of invention output, and its impact on the diversification of technological capabilities may be stronger than its effect on the specialization of technological capabilities. Therefore, explorative learning induced by external CV is an effective means of building new technological capabilities for the established firm, expanding its technology portfolio and then achieving competitive advantage. The following hypothesis is learned on the preceding discussion:

H1: External CV facilitates an established firm's broadening of its technological scope.

2.2. The moderator of complementary assets

A firm invests in external CV, leading to a highly diversified technology portfolio, which is difficult to connect with developing multidisciplinary technologies and likely to involve high R&D, coordination and communication costs (Granstrand and Oskarsson, 1994). These problems can be attributed to several tasks, such as scanning for technological opportunities, coordinating diversified R&D professionals in different fields, setting up different types of manufacturing facilities, and integrating new technologies with a firm's existing ones (Quintana-Garcia and Benavides-Velasco, 2008). To solve these problems, firms may thus consider whether they are following a coherent pattern of technological scope, one that clusters around groups of technological capabilities that share a common or complementary resource base or entail similar learning processes (Breschi et al., 2003).

Technological scope is not entirely exogenous, as it comes not only from searching for technological opportunities, but also from the inherent breadth of a body of firms' resources (Miller, 2006). In line with this notion, a firm may pursue particular technological trajectories rather than go beyond common resources to seek novel technologies over time. Breschi et al. (2003) have suggested that a firm's technological trajectories are linked by their knowledge-relatedness. Firms may span more than one technology because the same type of knowledge is used in more than one technology. Moreover, the relatedness among two or more technologies may be due to their resource complementarities or similarities. Based on the above point, managers engaging in external CV should consider how far and in what direction firms pursue links in their common resource portfolio. We thus attempt to offer the "complementary assets" view (Teece, 1986), demonstrating complementary assets as governable factors for firms engaging in external CV to consider in shaping their direction, with regard to technological scope.

Teece (1986) proposed that "complementary assets" are the critical resources that allow firms to capture the profits associated with technological innovation. Moreover, the new technologies are of little value in the absence of complementary assets, especially the specialized[1] complementary assets

[1] Complementary assets can be classified into three types: generic, specialized and co-specialized (Teece, 1986). Generic complementary assets need not be adjusted to innovation because they can frequently be contracted for in the market on competitive terms. Specialized complementary assets exhibit unilateral dependence between the innovation and complementary assets. The concept of cospecialized complementary assets refers to bilateral dependence. Because the distinction between unilateral and bilateral dependence of innovation and the complementary assets in question is not critical to our analysis, we use the term "specialized complementary assets" to denote both specialized and co-specialized assets.

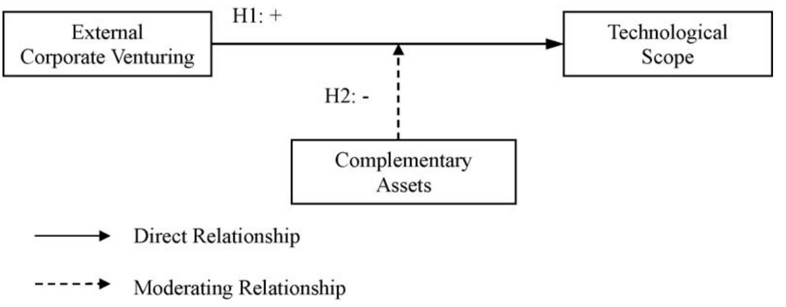

Fig. 1. Conceptual framework.

characterized in Teece's (1986) seminal work. The existence of specialized complementary assets that are difficult for competitors to imitate can also contribute to the sustainability of the competitive advantage created by firms. Based on the RBV of the firm, specialized complementary assets can be regarded as VRIN resources. When the complementary assets possessed by the firms are rich and special, firms may benefit by exploiting their attractive resources for future technological development (Rothaermel and Hill, 2005). Attempting to take advantage of such assets, firms engaging in external CV must follow their existing technology trajectories in order to create technological interdependencies within firms (e.g., Castiaux, 2007).

On the other hand, once a firm gains profits successfully by exploiting specialized complementary assets, it tends to implement practices that require these assets repeatedly (Christmann, 2000). Firms are therefore willing to invest considerable resources in establishing their specialized complementary assets. Routines may be formed through the above processes. Consequently, firms should consider the nature of technological interdependencies in accessing their specialized complementary assets while they engage in external CV to develop new technological capabilities. In this regard, firms tend to commit to existing technologic trajectories rather than broadening their technological scope. The specialized complementary assets will govern the firm's future decisions regarding technological scope. This logic suggests the following hypothesis:

H2: Although external CV facilitates the broadening of an established firm's technological scope, increasing investments in specialized complementary assets will drive the convergence of its technological scope.

The conceptual framework underlying this research is presented in Fig. 1.

3. Methods

3.1. Sample

To test the hypotheses, this study uses a panel data set containing patents, operations, and financial information during the period between 1997 and 2006 for firms listed in the Electronic and Information Technology category of two stock markets in Taiwan (the Taiwan Stock Exchange (TSE) and the Taiwan Over-the-Counter Securities Exchange (TOSE)). Electronics and information technology firms in Taiwan were chosen for the following reasons. First, technological activities have a vital role in firm growth in these industries compared with other industries in Taiwan. Second, most firms are contract manufacturers. Contractual agreements with globally branded buyers in these industries have prompted Taiwanese firms to upgrade their technological capabilities within the global production system. Through external CV, these firms have subsequently built and leveraged technological capabilities to provide post-architecture product designs and manufacturing services for specialized or diversified electronics and information technology products to globally branded buyers. The choice of technological scope exists in these industries. These firms have grown during recent years, and many have achieved remarkable performance. The total output for these electronics and information technology firms is the fourth-largest worldwide (*Business Week*, May

16, 2005: 76–81). Electronics and information technology firms in Taiwan are thus appropriate for use in testing these hypotheses.

3.2. Data collection

As mentioned above, the sample firms selected for this empirical study are chosen from firms listed in the Electronic and Information Technology category of the TSE and TOSE during 1997–2006. To examine the hypotheses, firm-level patents and operating and financial data are required. Firm-level patent data are computed using the International Patent Classification (IPC) obtained from the Taiwan Patent Database established by the Intellectual Property Office (IPO) of the Ministry of Economic Affairs, Taiwan. The patents granted to a firm annually are registered in the IPO by IPC. Financial data for each sample firm are acquired from the Taiwan Economic Journal and Market Observation Post System (established by the TSE), with both databases containing the financial information reported to each sample firm.

At the end of 2006, 639 firms were listed in the Electronic and Information Technology category of the TSE and TOSE. Since this study focuses on firm technological diversification, 56 electronics and information distributors not related to technological diversification activities were excluded. Thus, the final sample had 583 firms. This sample set contains a mixture of firms across several segments of industry value chains, including manufacturers of semiconductors, motherboards, photonics, networking and communication equipment, electronic components, electronic equipment, software, consumer electronics, and IC manufacturers and system assemblers. This sample selection comprised a panel data set with complete information for 583 firms for 1997–2006 (2031 firm-year observations).

3.3. Dependent variable

3.3.1. Technological scope measure

Patents are a reasonable indicator of technological development because they represent the outcome of technological capabilities (Haupt et al., 2007). This study measured technology scope using the entropy approach for the total number of patents during 1997–2006 (e.g., Zander, 1997; Gemba and Kodama, 2001). This measure has been widely utilized in the literature measuring diversification (e.g., Jacquemin and Berry, 1979; Palepu, 1985; Hitt et al., 1997). One of the most significant benefits of the entropy approach in measuring technological scope is that it can be decomposed into elements that assess the contribution of technological scope at various levels of aggregation of the total stock of patents in a firm (Zander, 1997). For each firm, its technological scope is computed by IPC and calculated using the following method: With 362 technological fields indexed by $m = 1,\ldots,362$ in the sample firms, this entropy approach accounts for both the number of technologies in which a firm might be active and the relative distribution of technological activity across technologies (Zander, 1997):

$$\text{Technological scope} = \sum_{j=1}^{m}\left[P_{ij}\ln\left(\frac{1}{P_{ij}}\right)\right],$$

where P_{ij} is the share of category j of the total stock of patents in firm i, and $\ln(1/P_{ij})$ is the weight of each patent segment. The value of the entropy measure ranges between zero and $\ln n$, where a value of zero represents a firm's concentrating on one technology only and a value approaching $\ln n$ represents a firm with an even distribution of patents across n segments. Thus, increased *technological scope* implies that a firm has a high degree of diversified technological capabilities that lead to technological diversification; conversely, a small value for *Technological scope* indicates that a firm is specialized in its technological capabilities, which are closely related to its existing technological scope.

3.4. Independent variables

3.4.1. External corporate venturing measure

The primary independent variable is *External CV*, which is calculated as all long-term assets invested via all external CV funds for an established firm in a year divided by the book value of the total assets. In line with the definition of external CV in Section 2, corporate venture capital, joint ventures and acquisitions can be included in our external CV measure. This measure indicates that the established firms' investment ratios for external CV facilitate the examination of relationships between external CV and technological scope. This variable is continuous and observable over time. When the value of *External CV* is large, an established firm has invested a large portion of its assets in external CV. Thus, the increased number of controls allows established firms to integrate external CV activities with their overall strategy and activities. Data for the value of the shipments were obtained from the Taiwan Economic Journal and Market Observation Post System.

3.4.2. Complementary assets measure

Prior studies on complementary assets lack consistent measurements (Christmann, 2000; Colombo et al., 2006). It is very difficult to measure the concept of complementary assets, especially when one has to distinguish between generic assets and specialized assets. However, consistent with Teece (1986), both qualitative and quantitative analyses have confirmed that if a firm has proprietary access to the complementary assets necessary for the commercial exploitation of an innovation, then that firm has a distinct advantage. To examine complementary assets, this study introduces the variable *Complementary assets*, which is constructed based on the following formula that approximates complementary assets within established firms.

$$\text{Complementary assets} = \frac{\text{Manufacturing Overhead}}{\text{Total Sales Revenue}} \times \text{VAD Ratio}.$$

Manufacturing overhead accounts for complementary assets during production. To eliminate firm size effects—a large firm will naturally have more expenses than a small firm—total sales revenue for each firm is considered. The value-added (VAD) ratio represents the extent of the specialized complementary assets. When the value of the VAD ratio is large, firms typically have a high degree of motivation to utilize these specialized resources (e.g., Chiu et al., 2008; Lai et al., 2009) and continually use substantial amounts of resources to maintain and reproduce their actions. To calculate the VAD ratio, the following equation is used: Value-added = (Net operating income − Consumption of raw material − Purchase of the year − Work-in-process goods purchased − Manufacturing expense); VAD ratio = Value-added/Net sales of a firm.

The decision to adopt this complementary assets measure in the analysis is based on the following reasons. First, in line with Teece (1986), specialized complementary assets are generally idiosyncratic and valuable; they are also difficult to imitate and can therefore be a source of competitive advantage. The existence of specialized complementary assets can enhance the profitability of innovation. In other words, the profitability of innovation can be determined by the value of a firm's specialized complementary assets. We thus introduce the notion of the VAD ratio to represent how many value-added benefits can be generated from these idiosyncratic and valuable resources within a firm.

Second, most firms in Taiwan's electronics and information technology industries are contract manufacturers that must invest considerable capital in purchases and maintain manufacturing facilities to meet buyer needs. Thus, the sample firms in this study did confront significant complementary assets in this context; as a result, manufacturing overhead accounts for complementary assets during production are appropriate for this analysis. Finally, prior studies have suggested that firms' investments in manufacturing equipment are not only a complementary asset for firms, but also one of their sunk costs (Rothaermel and Hill, 2005). Once such assets possessed by firms are rich, firms benefit by continually exploiting these assets.

3.5. Control variables

Six potential sources of technological scope that must be controlled during analysis exist in this empirical context.

3.5.1. Firm age

The variable *Firm age* indicates the number of years from incorporation to the present (e.g., Mishina et al., 2004). Firm age in this study is obtained by searching the Market Observation Post System, company websites, and corporate annual reports.

3.5.2. Firm size

Firm size is measured using the natural logarithm of total sales revenue of sample firms at the corporate level (e.g., Hitt et al., 1997). Diversity of technology is positively related to firm sales growth (Suzuki and Kodama, 2004). Firm size in this study is obtained by searching the Market Observation Post System.

3.5.3. Competition within industry

Industry average advertising intensity in this study is utilized to measure within-industry competition and is constructed based on average advertising expenditures for all firms (TSE and TOSE) divided into each firm's primary industry segment (e.g., Zahra, 1993).

3.5.4. Attractiveness of industry

The variable *Industry average profitability* is utilized to measure industry attractiveness and is constructed based on average ROA. The data for shipment value were obtained from the Taiwan Economic Journal and Market Observation Post System.

3.5.5. Environmental munificence

Environmental munificence is a measure of the richness of external resources for future growth and is measured as the regression slope coefficient divided by the mean value for the regression of time against the shipment value in the industry for all firms (TSE and TOSE) divided into each firm's primary industry segment (e.g., Zahra, 1993; Mishina et al., 2004).

3.5.6. Environmental dynamism

Environmental dynamism represents environmental changes measured as the standard error of the regression slope divided by the mean value of shipments using the same regression models as those used in calculating environmental munificence (e.g., Zahra, 1993; Mishina et al., 2004).

Moreover, to test our arguments, we analyze the impacts of external CV on firm technological scope for each firm-year. Time-deferred effects influence firm technological scope. This study thus used the same formula for analysis as was used to construct external CV and complementary assets; however, instead of incorporating these variables by firm i in year t, this study counted these independent and control variables for firms in 1997–2006 and the preceding year ($t-1$).

3.6. Regression analysis

To test the hypotheses, regression analysis was implemented. The data utilized in this study include cross-section and profile. Additionally, "firm × year" is used as the analytical unit in this study, and the data may face problems generated by unbalanced samples. To resolve this problem, a panel model was utilized for regression analysis. Hausman's test demonstrated that samples could best be examined with a random effect. In terms of models, the regression model is as follows:

$$Y_{it} = b_0 + b_1 X_{1it-1} + b_2 X_{2it-1} + b_3 X_{1it-1} X_{2it-1} + \text{control variables}_{t-1} + e_{it-1}$$

Y_{it} is technological scope of i firms in term t, b_0 is intercept, shown randomly (each cross-section represents a model), t = 1997–2006 (the time period of the investigation), i = 1, 2, . . ., 583 (the number of firms included in the sample), X_{kit-1} is K independent variables (including the control variable) of i firms in term $t-1$, X_{1it-1}, X_{2it-1} is interaction term $t-1$ of external CV and complementary assets, and e_{it-1} is error term $t-1$.

4. Results

Table 1 presents means, standard deviations, and intercorrelations for all variables. The correlations among independent variables and other diagnostic tests suggest no multi-collinearity problems.

Table 2 presents the results of the regression analysis for the hypotheses. In Model 1, the effects of control variables (*Firm age*$_{t-1}$, *Firm size*$_{t-1}$, *Environmental munificence*$_{t-1}$, *Environmental dynamism*$_{t-1}$,

Table 1
Descriptive statistics and Pearson correlations coefficients.

Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9
1. Technology scope	0.967	0.751	1								
2. Firm age$_{t-1}$	15.100	8.633	0.053*	1							
3. Firm size$_{t-1}$[a]	6.179	0.686	0.432**	0.246**	1						
4. Environmental munificence$_{t-1}$	0.173	0.045	−0.058**	0.204**	0.010	1					
5. Environmental dynamism$_{t-1}$	0.045	0.020	−0.049*	0.214**	−0.011	0.237**	1				
6. Industry average advertising intensity$_{t-1}$	0.063	0.032	−0.048*	−0.071**	−0.248**	−0.084**	−0.069**	1			
7. Industry average profitability$_{t-1}$	0.107	0.032	0.001	0.057**	−0.011	0.187**	0.186**	−0.072*	1		
8. External corporate venturing$_{t-1}$	0.141	0.148	0.149**	0.454**	0.217**	0.189**	0.187**	−0.030*	−0.034*	1	
9. Complementary assets$_{t-1}$	0.251	0.189	−0.125**	−0.090**	−0.053**	0.058**	−0.022	−0.020	0.101**	−0.331**	1

* $P < 0.05$
** $P < 0.01$.
[a] Logarithm.

Table 2
Results of external corporate venturing and complementary assets on technological scope[a,b].

Independent variables	Model 1	Model 2	Model 3	Model 4
Firm age$_{t-1}$	−0.003	−0.006**	−0.006**	−0.006*
Firm size$_{t-1}$[b]	0.425***	0.447***	0.448***	0.446***
Environment munificence$_{t-1}$	0.362	0.256	0.295	0.197
Environment dynamics$_{t-1}$	−1.315	−1.284	−1.347	−1.395
Industry average advertising intensity$_{t-1}$	0.078*	0.049	0.050.	0.052
Industry average profitability$_{t-1}$	1.131**	1.406***	1.416***	1.561***
External corporate venturing$_{t-1}$		0.416***	0.378***	0.802***
Complementaryassets $_{t-1}$			−0.085	0.119
External corporate venturing$_{t-1}$ × complementary assets$_{t-1}$				−2.692***
Constant	−1.926***	−2.09***	−2.07***	−2.111***
Adjusted R^2	0.1924	0.2058	0.2094	0.2185
Wald χ^2 (d.f.)	233.37(6)	256.09 (7)	263.48 (8)	271.06 (9)
Wald test χ^2		22.72***	7.39***	11.58***

[a] *$P<0.1$, **$P<0.05$, ***$P<0.01$.
[b] Logarithm.

Industry average advertising intensity$_{t-1}$ *and Industry average profitability*$_{t-1}$) on *Technological scope* were analyzed. The analytical results reveal that *Firm size*$_{t-1}$, *Industry average advertising intensity*$_{t-1}$ and *Industry average profitability*$_{t-1}$ have significant and positive effects on *Technological scope*. Model 2 adds *External CV*$_{t-1}$ as an explanatory variable.

Model 2 examines the main effect of *External CV*$_{t-1}$ on *Technological scope*; a significant and positive relationship was found between external CV and technological scope (Wald test $\chi^2 = 22.72$; $P < 0.01$). This analytical result supports Hypothesis 1. Therefore, established firms have an extended technological scope through external CV.

Model 4 (Table 2) shows the interactive effect of *External CV*$_{t-1}$ and *Complementary assets*$_{t-1}$ on *Technological scope*. The significantly negative effect of the interaction on technological scope supports Hypothesis 2 (Wald test $\chi^2 = 11.58$; $P < 0.01$). This study indicates that complementary assets moderate the relationship between external CV and technological scope. Moreover, the negative relationship indicates that established firms tend to reduce technological diversification and increase technological specialization. This suggests that firms engaging in external CV will counter this trend, resulting in a higher likelihood of technological specialization due to increasing investments in complementary assets.

5. Discussion

The contributions of this study are fourfold. First, this study analyzed the argument that the degree of technological specialization and diversification rests on a single continuum rather than as two independent choices for firms. The analytical results support our argument that technological specialization and diversification are two ends of a continuum (e.g., Breschi and Malerba, 1999). Firms can vary their degree of specialization or diversification of technological fields along this tradeoff continuum. In this study, a firm engaging in external CV is a point along this continuum; moreover, a critical driver of the tradeoff continuum is the degree of investment in specialized complementary assets.

Second, external CV has a significant and positive effect on an established firm's technological scope. This finding contributes to CV literature by discussing how external CV influences firms' technological scope, a topic that is not really discussed in the literature. Moreover, our argument contributes to the technological diversification literature (e.g., Fai, 2003), suggesting that firms must rely more on external collaborative organizations to master new technological breakthroughs. This study uses the organizational contexts, RBV and organizational learning, as a theoretical basis for elucidating how external CV enables firms to monitor the opportunities represented by the technologies, obtain technological resources previously beyond firm boundaries, and create new technological capabilities through learning.

The analytic results confirmed that firms use their external CV activities to broaden their technological scope. In line with previous CV literature (e.g., Ireland et al., 2003; Keil, 2004; Narayanan et al., 2009), we applied RBV to discuss acquiring new resources through external CV, which provides the foundation for developing new technological capabilities. This study suggests that continuous evaluation of the potential for an existing resource portfolio to create synergy when combined with other resources is required. External CV can be regarded as a tool to supplement the insufficiency of a resource portfolio in order to capture changing technological opportunities.

Moreover, we introduce the organizational learning perspective to explore how firms tend to utilize their acquired external resources for more explorative learning and then build new technological capabilities. In this regard, this study parallels CV literature (e.g., Dess et al., 2003; Ravasi and Turati, 2005; Bierly et al., 2009; Zahra et al., 2009), indicating that external CV can create significant opportunities for multifaceted learning to promote generation of new capabilities. Organizational learning induced by external CV is an effective means of building new technological capabilities for the established firm, expanding its technology portfolio.

On the other hand, Hypothesis 1 helps us to recognize the role of external CV in knowledge creation and utilization as well as learning. Furthermore, this argument encourages us to open the black box that pervades the CV literature on the relationship between knowledge, organizational learning and capability-building (e.g., Dess et al., 2003). Our finding also offers a piece of evidence to support the investigable relationship in the seminal work by Dess et al. (2003).

Third, analytical findings call into question the idea that a firm's decisions regarding technological scope may be traced to a specific factor that governs the extent of technological specialization and diversification. This study defines this factor as the element of complementary assets associated with established firms. Over-diversification, or diversification in inappropriate technological directions, may cause the firm to lose control over its capability-leveraging and -building: in other words, its organizational coherence (Fai, 2003).

We propose that complementary assets can solve the above problems inducing by increasing investment in external CV. The results support the idea that increasing investments in specialized complementary assets will urge firms engaging in external CV to concentrate their technological scope. Our suggestion also parallels the idea (e.g., Rothaermel, 2001; Lavie and Rosenkopf, 2006) that firms with specialized complementary assets tend to engage in relevant domains to create synergies, which reduces R&D uncertainty and costs.

On the other hand, past resource investments affect what managers can do today. When an established firm engages external CV, their complementary assets directly influence the choice of technological scope. This suggestion is in accord with the evolutionary perspective in which technological change is perceived as a path-dependent process in which complementary assets play a key role. The repeated application of specialized complementary assets eventually exhausts the particular technological trajectories, which expand a core set of technological capabilities that are favored by specialized complementary assets. This study thus addresses the idea that particular technological trajectories are the conjunction of both technological capabilities and specialized complementary assets rather than determined by either individually (e.g., Christmann, 2000; Rothaermel and Hill, 2005; Castiaux, 2007).

Furthermore, most sample firms are manufacturers in Taiwan's electronics and information technology industries; thus, manufacturing overhead accounts for complementary assets during production are appropriate for use in this analysis. This study also introduces the VAD ratio as representative of the extent of value added for established firms to gain from their investment in specialized complementary assets. We contribute to complementary assets literature to provide a feasible measure for specialized complementary assets.

Finally, the analytical results indicated that "*Firm size*" significantly and positively impacts "*Technological scope*" (see Model 4 in Table 2). This result provides empirical evidence to support the argument of technological diversification literature (e.g., Granstrand et al., 1997; Pavitt et al., 1989) that larger firms tend to become multi-technology in their orientation. From RBV, larger firms usually have abundant resources that they use in order to operate their multifarious functional activities. Therefore, they are much more motivated to explore and exploit new technological opportunities emerging from their production systems and supply chains than are smaller firms. Large firms would develop a broader set of technological capabilities by exploiting their abundant resources. On the other hand, regarding the significant and positive relationship between "*Industry average profitability*" and "*Technological scope*" (see Model 4 in Table 2), this result implies that managers are strongly motivated to expand their resources and capabilities in order to develop new products or processes in an attractive industry. The breadth of technological scope thus is expected to increase within firms.

6. Conclusion

Utilizing two theoretical perspectives, RBV and organizational learning, this study empirically demonstrates how the external CV of established firms influences their technological scope. The findings also contribute to some implications for firms that are engaging in external CV in order to manage their technological scope. Further, this study calls into question the notion that external CV does not broaden a firm's technological fields over time.

We advance research on complementary assets by exploring their effects on the use of external partners for firm technological development. The analytical results' implication for firms is the suggestion that they exploit resource commonalities in their complementary assets while investing in external CV to facilitate the coordination of their technology portfolios by creating synergy between external partners. Resolving the issue regarding the effects of complementary assets is essential because it is relevant to firms that want to build technological capabilities by collaborating with different external partners. The existing external CV literature contains scant information as to how external CV influences technological scope and complementary assets govern a firm's decisions regarding technological scope. This study developed and tested two hypotheses in an effort to fill the gap in the literature on this topic.

7. Directions for future research

Future research should overcome some limitations of this study. First, firm tendencies toward technological diversification or specialization may be driven by other factors. Following this perspective, future research can investigate how other factors moderate the relationship between external CV and firms' technological scope. Second, future research can further analyze the performance implications of the tendency toward technological diversification or specialization in the context of external CV. Third, future research can use questionnaires or quantitative research to investigate the greater role that explorative learning tends to play in comparison with exploitative learning in firms' external CV activities. This could offer empirical evidence in this regard while simultaneously presenting results and findings in a more accurate manner.

Finally, future research can investigate and compare how the different external CV modes (e.g., corporate venture capital, joint ventures and acquisitions) affect firms' technological scope. On the other hand, future studies can use surveys to explore another mode of external CV—strategic alliances—in which the partners have collaborated. Such a study could identify the full range of external CV modes and differentiate between these modes explicitly in terms of the extent to which technological scope can be pursued. Despite these limitations, this study contributes to the literature on external CV by shedding light on the significance of complementary assets in the choice of technological scope.

Acknowledgments

This paper has benefited greatly from the comments and suggestions from the Editor-in-Chief and three anonymous reviewers. The authors would like to gratefully acknowledge the financial support for this research from the National Science Council, Taiwan (NSC97-2410-H-024-017).

References

Barney, J.B., 1991. Firm resources and sustained competitive advantage. Journal of Management 17 (1), 99–120.
Berends, H., Vanhaverbeke, W., Kirschbaum, R., 2007. Knowledge management challenges in new business development: case study observations. Journal of Engineering and Technology Management 24 (4), 314–328.
Bierly III, P.E., Damanpour, F., Santoro, M.D., 2009. The application of external knowledge: organizational conditions for exploration and exploitation. Journal of Management Studies 46 (3), 481–509.
Birkinshaw, J., Hill, S., 2005. Corporate venturing units as vehicles for strategic success in the new Europe. Organizational Dynamics 34 (3), 247–256.
Breschi, S., Lissoni, F., Malerba, F., 2003. Knowledge-relatedness in firm technological diversification. Research Policy 32 (1), 69–87.
Breschi, S., Malerba, F., 1999. Diversification and specialisation in innovative activities: an analysis of patenting activity of electronic firms, DYNACOM Working Paper.
Business Week, 2005. Why Taiwan Matters. May 16, 76–81.
Castiaux, A., 2007. Radical innovation in established organizations: being a knowledge predator. Journal of Engineering and Technology Management 24 (1–2), 36–52.
Chiu, Y.C., Lai, H.C., Lee, T.Y., Liaw, Y.C., 2008. Technological diversification, complementary assets, and performance. Technological Forecasting & Social Change 75 (6), 875–892.
Christmann, P., 2000. Effect of "best practices" of environmental management on cost advantage: the role of complementary assets. Academy of Management Journal 43 (4), 663–680.
Colombo, M.G., Grilli, L., Piva, E., 2006. In search of complementary assets: the determinants of alliance formation of high-tech star-ups. Research Policy 35 (8), 1166–1199.
Covin, J.G., Miles, M.P., 2007. Strategic use of corporate venturing. Entrepreneurship Theory and Practice 31 (2), 183–207.
Dess, G.G., Ireland, R.D., Zahra, S.A., Floyd, S.W., Janney, J.J., Lane, P.J., 2003. Emerging issues in corporate entrepreneurship. Journal of Management 29 (3), 351–378.
Fai, F.M., 2003. Corporate Technological Competence and the Evolution of Technological Diversification. Edward Elgar, Cheltenham, UK.
Garcia-Vega, M., 2006. Does technological diversification promote innovation? An empirical analysis for European firms. Research Policy 35 (2), 230–246.
Gemba, K., Kodama, F., 2001. Diversification dynamics of the Japanese industry. Research Policy 30 (8), 1165–1184.
Granstrand, O., Oskarsson, C., 1994. Technological diversification in multi-tech corporations. IEEE Transactions on Engineering Management 41 (4), 355–364.
Granstrand, O., Patel, P., Pavitt, K., 1997. Multi-technology corporations: why they have "distributed" rather than "distinctive core" competencies. California Management Review 39 (4), 8–25.
Haupt, R., Kloyer, M., Lange, M., 2007. Patent indicators for the technology life cycle development. Research Policy 36 (3), 387–398.
Helfat, C.E., 2000. Guest editor's introduction to the special issue: the evolution of firm capabilities. Strategic Management Journal 21, 955–959.
Hitt, M.A., Hoskisson, R.E., Kim, H., 1997. International diversification and firm performance in product-diversified firms. Academy of Management Journal 40 (4), 767–798.
Ireland, R.D., Hitt, M.A., Sirmon, D.G., 2003. A model of strategic entrepreneurship: the construct and its dimensions. Journal of Management 29 (6), 963–989.
Jacquemin, A.P., Berry, C.H., 1979. Entropy measure of diversification and corporate growth. Journal of Industrial Economics 27 (4), 359–369.
Keil, T., Maula, M., Schildt, H., Zahra, S.A., 2008. The effect of governance modes and relatedness of external business development activities on innovative performance. Strategic Management Journal 29, 895–907.
Keil, T., 2004. Building external corporate venturing capability. Journal of Management Studies 41 (5), 799–825.
Keil, T., 2002. External Corporate Venturing: Strategic Renewal in Rapidly Changing Industries. Quorum, Westport, CT.
Keil, T., 2001. External corporate venturing: exploration and exploitation. Institute of Strategy and International Business Series, Working Paper.

Kogut, B., 1988. Joint ventures: theoretical and empirical perspectives. Strategic Management Journal 9, 319–332.
Lai, H.C., Chiu, Y.C., Liaw, Y.C., Lee, T.Y., 2009. Technological diversification and organizational divisionalization: the moderating role of complementary assets. British Journal of Management DOI: 10.1111/j.1467-8551.2009.00630.x.
Lavie, D., Rosenkopf, L., 2006. Balancing exploration and exploitation in alliance formation. Academy of Management Journal 49 (4), 797–818.
Miller, D.J., 2006. Technological diversity, related diversification, and firm performance. Strategic Management Journal 27 (7), 601–619.
Mishina, Y., Pollock, T.G., Porac, J.F., 2004. Are more resources always better for growth? Resource stickiness in market and product expansion. Strategic Management Journal 25 (12), 1179–1197.
Morrow, J.L., Sirmon, D.G., Hitt, M.A., Holcomb, T.R., 2007. Creating value in the face of declining performance: firm strategies and organizational recovery. Strategic Management Journal 28, 271–283.
Narayanan, V.K., Yang, Y., Zahra, S.A., 2009. Corporate venturing and value creation: a review and proposed framework. Research Policy 38 (1), 58–76.
Palepu, K., 1985. Diversification strategy, profit performance, and the entropy measure of diversification. Strategic Management Journal 6 (3), 239–255.
Pavitt, K., Robson, M., Townsend, J., 1989. Technological accumulation, diversification, and organisation in U.K. companies, 1945–1983. Management Science 35 (1), 81–99.
Peteraf, M.A., 1993. The cornerstones of competitive advantage: a resource-based view. Strategic Management Journal 14 (3), 179–191.
Priem, R.L., Butler, J.E., 2001. Is the resource-based "view" a useful perspective for strategic management research? Academy of Management Review 26 (1), 57–66.
Quintana-Garcia, C., Benavides-Velasco, C.A., 2008. Innovative competence, exploration and exploitation: the influence of technological diversification. Research Policy 37 (3), 492–507.
Ravasi, D., Turati, C., 2005. Exploring entrepreneurial learning: a comparative study of technology development projects. Journal of Business Venturing 20 (1), 137–164.
Rothaermel, F.T., Hill, C.W.L., 2005. Technological discontinuities and complementary assets: a longitudinal study of industry and firm performance. Organization Science 16 (1), 52–70.
Rothaermel, F.T., 2001. 'Incumbent's advantage through exploiting complementary assets via interfirm cooperation'. Strategic Management Journal 22, 687–699.
Schildt, H.A., Maula, M.V.J., Keil, T., 2005. Explorative and exploitative learning from external corporative ventures. Entrepreneurship Theory and Practice 29 (4), 493–515.
Schoenmakers, W., Duysters, G., 2006. Learning in strategic technology alliances. Technology Analysis & Strategic Management 18 (2), 245–264.
Suzuki, J., Kodama, F., 2004. Technological diversity of persistent innovators in Japan: two case studies of large Japanese firms. Research Policy 33 (3), 531–549.
Teece, D., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strategic Management Journal 18 (7), 509–533.
Teece, D.J., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Research Policy 15 (6), 285–305.
Tyler, B.B., 2001. The complementarity of cooperative and technological competencies: a resource-based perspective. Journal of Engineering and Technology Management 18 (1), 1–27.
Wang, C.L., Ahmed, P.K., 2007. Dynamic capabilities: a review and research agenda. International Journal of Management Reviews 9 (1), 31–51.
Weber, B., Weber, C., 2007. Corporate venture capital as a means of radical innovation: relational fit, social capital, and knowledge transfer. Journal of Engineering and Technology Management 24 (1–2), 11–35.
Wilbon, A.D., 1999. An empirical investigation of technology strategy in computer software initial public offering firms. Journal of Engineering and Technology Management 16 (2), 147–169.
Zahra, S.A., Filatotchev, I., Wright, M., 2009. How do threshold firms sustain corporate entrepreneurship? The role of boards and absorptive capacity. Journal of Business Venturing 24 (3), 248–260.
Zahra, S.A., George, G., 2002. Absorptive capacity: a review, reconceptualization, and extension. Academy of Management Review 27 (2), 185–203.
Zahra, S.A., Nielson, A.P., Bogner, W.C., 1999. Corporate entrepreneurship, knowledge, and competence development. Entrepreneurship Theory and Practice 23 (3), 169–189.
Zahra, S.A., 1993. Environment, corporate entrepreneurship, and financial performance: a taxonomic approach. Journal of Business Venturing 8 (4), 319–340.
Zander, I, 1997. Technological diversification in the multinational corporation-historical evolution and future prospects. Research Policy 26 (2), 209–227.