Citation: Huang, T-T. Chen, L. Stewart, R.A. Panuwatwanich, K. (2013) Leveraging power of learning capability upon manufacturing operations, *International Journal of Production Economics*, Volume 145, Issue 1, 233-252, ISSN 0925-5273, http://dx.doi.org/10.1016/j.ijpe.2013.04.042.

Leveraging power of learning capability upon manufacturing operations

Authors:

The first author:

Dr. Tsu-Te Andrew Huang
Research Fellow
Centre for Infrastructure Engineering & Management
Griffith University,
Gold Coast Campus,
Queensland 4222, Australia
Tel: (617) 5552 9057
Fax: (617) 5552 8065
Email: andrew.huang@griffith.edu.au

The second author and the corresponding author to whom the page proofs are to be sent.

Dr. Le Chen[1]
Postdoctoral Fellow
Department of Building and Real Estate
The Hong Kong Polytechnic University
Hung Hom, Kowloon, Hong Kong
Tel: (852) 2766 5873
Fax: (852) 2764 5131
Email: kminno.chen@gmail.com

The third author:

Dr. Rodney A. Stewart
Associate Professor, Griffith School of Engineering
Director, Centre for Infrastructure Engineering & Management
Gold Coast Campus, Griffith University
Queensland 4222, Australia
Tel: (617) 5552 8778
Fax: (617) 5552 8065
Email: r.stewart@griffith.edu.au

The fourth author:

Dr. Kriengsak Panuwatwanich
Lecturer, Engineering Management
Griffith School of Engineering
Gold Coast campus, Griffith University
Queensland 4222, Australia
Tel: (617) 5552 7357
Fax: (617) 5552 8065
Email: k.panuwatwanich@griffith.edu.au

Key words: Dynamic capabilities, operational capabilities, routines, new product development, supplier integration.

Abstract:

[1] Present address: Dr. Le Chen, Research Fellow, School of Civil Engineering and Built Environment, Queensland University of Technology, 2George St GPO Box 2434, Brisbane, Qld 4001, Australia. Tel: 617 3138 1151, Fax: 617 3138 1170, E-mail: le.chen@qut.edu.au

Learning capability (LC) is a special dynamic capability that a firm purposefully builds to develop a cognitive focus, so as to enable the configuration and improvement of other capabilities (both dynamic and operational) to create and respond to market changes. Empirical evidence regarding the essential role of LC in leveraging operational manufacturing capabilities is, however, limited in the literature. This study takes a routine-based approach to understand capability, and focuses on demonstrating leveraging power of LC upon two essential operational capabilities within the manufacturing context, i.e., operational new product development capability (ONPDC), and operational supplier integration capability (OSIC). A mixed-methods research framework was used, which combines sources of evidence derived from a survey study and a multiple case study. This study identified high-level routines of LC that can be designed and controlled by managers and practitioners, to reconfigure underlying routines of ONPDC and OSIC to achieve superior performance in a turbulent environment. Hence, the study advances the notion of knowledge-based dynamic capabilities, such as LC, as routine bundles. It also provides an impetus for managing manufacturing operations from a capability-based perspective in the fast changing knowledge era.

1. Introduction

In strategic management literature, organizational routines have been perceived as the foundation of capabilities (Eisenhart and Martin, 2000; Nelson and Winter, 1982; Teece, 2007). These routines are broadly defined as regular and predictable patterns of behaviors, or the way work is done (Teece et al., 1997), and have a wide range of variations. Some are constantly changing, while others are relatively static, which indicates the underlying phenomena and dynamics (Pentland and Feldman, 2005). Static operational capabilities are created by a collection of operating routines that execute procedures for the purpose of generating current revenue and profit (Nelson and Winter, 1982; Zollo and Winter, 2002). Dynamic capabilities are created by a collection of search routines that bring about desirable changes in the existing set of operating routines or the development of new ones, in order to sustain competitive advantage in a rapidly changing environment (Helfat et al., 2007; Kyläheiko et al., 2002). In other words, operational or 'zero-level' capabilities are those that permit a firm to generate revenue and profit, in the short term, while dynamic capabilities are 'higher-level' capabilities that operate to extend, modify or create operational capabilities for the purpose of enhancing profit in the future (Winter, 2003; Zollo and Winter, 2002).

It has been asserted that deliberate organizational learning is responsible for modifying and renewing both dynamic and operational capabilities, over time (Kyläheiko et al., 2002; Zollo and Winter, 2002). Accordingly, knowledge-based learning capability (LC) is perceived as a highly intelligent dynamic capability that enables both knowledge exploration and exploitation (Azadegan and Wagner, 2011; March, 1991). The process facilitates the modification and configuration of capabilities, in particular, the operational capabilities (Nooteboom, 2009). The strategic importance of LC hence lies in its ability to create cognitive mechanisms that can innovatively respond to market changes.

The advent of rapidly advancing information technologies and fierce global competition has changed the traditional business models of manufacturing firms. Innovative new product development (NPD) and supplier integration have become underlying routines of essential operational manufacturing capabilities to effect performance outcomes (Marsh and Stock, 2006; Terpend et al., 2008). The degree to which operational capabilities produce superior performance appears to be affected by a certain collection of underlying routines of LC (e.g., Allred et al., 2011; da Silva Gonçalves Zangiski et al., 2013; Hull and Covin, 2010; Li et al., 2012; Pavlou and El Sawy, 2011; Peng et al., 2008). The leveraging power of learning contingencies upon the core manufacturing operational routines has been proposed (Azadegan et al., 2008). However, little research has been undertaken into how organizational learning engenders and modifies operational capabilities as bundles of interrelated yet distinct routines.

In view of this research need, the current study aims to investigate the leveraging power of LC in enabling operational NPD capability (ONPDC), as well as operational supplier integration capability (OSIC) to effect performance outcomes within a turbulent manufacturing industry. The study sought to answer two research questions: 1) Does LC moderate the relationships between operational manufacturing capabilities (i.e., ONPDC and OSIC) and performance outcomes? 2) How do certain underlying routines of LC reconfigure and modify specific underlying routines of ONPDC and OSIC within various manufacturing contexts?

Rather than focusing on producing an exhaustive set of measures for the capabilities under investigation, the primary objective of the study was to demonstrate how certain underlying routines of LC could be manipulated by managers and practitioners to redesign and enable specific operational routines of NPD and supplier integration, and so better match the market environment. To fulfill the research objective, a mixed methods research framework (Morse, 2003; Yin, 2009) was adopted. It combined the evidence derived from multiple sources, using quantitative and qualitative data collection and analytical techniques, in sequential phases.

Building upon the capability assertions as well as empirical evidence, established within the manufacturing context, the survey study was undertaken to empirically identify significant moderating effects of particular underlying routines of LC on those of ONPDC and OSIC, thereby providing answers for the first research question. An explanatory multiple-case study was subsequently undertaken to provide answers for the second research question.

The impetus for adopting the case study approach stemmed from the need to reveal the underlying insights of the relationships identified within real-life manufacturing contexts, as well as to uncover contextual conditions, which potentially influence the strength of modifying effects of LC. From a theoretical perspective, the study advanced the notion of knowledge-based dynamic capabilities, for example LC, as routine bundles, which enable manufacturing routines to robustly handle a turbulent business environment. The study not only identified specific high-level learning routines that could be manipulated by managers and practitioners to leverage their core operational manufacturing routines, but also highlighted the contextual conditions that potentially influence the degree of the leveraging effect. The findings have significant implications for manufacturing operations.

The remainder of the paper is structured as follows. Based on the literature review, the next section addresses the strategic importance of LC and posits its leveraging power, which matches ONPDC and OSIC with the market needs in a constantly changing environment. The mixed methods research framework is then presented, followed by the data analysis of both the survey study and the multiple-case study. The paper concludes with a discussion on the theoretical contributions, managerial implications and future research directions of LC in manufacturing operations.

2. Theory and hypotheses

2.1 Leveraging power of learning capability

The evolution of the research studies in the areas of knowledge management (e.g. Nonaka, 1994), absorptive capacity (e.g. Cohen and Levinthal, 1990) and dynamic capabilities (e.g. Zollo and Winter, 2002) have gradually led to an integrative conceptualization of a knowledge-based dynamic capability, which incorporates both internal and external learning routines (Lewin et al., 2011; Lichtenthaler and Lichtenthaler, 2009). The capability is purposely developed by a firm to reconfigure and realign learning routines which explore, retain and exploit both internal (intra-firm) and external (inter-firm) knowledge for achieving superior performance (Lewin et al., 2011; Lichtenthaler and Lichtenthaler, 2009).

The influential concept of absorptive capacity was initially proposed by Cohen and Levinthal (1990) as a firm's ability to recognize, assimilate and apply new knowledge from an external environment for sustaining competitive advantage through innovation. The later concept rectification conceptualizes absorptive capacity as a dynamic capability that is imbedded in higher-order learning routines, thereby recognizing its capacity to influence the reconfiguration of other capabilities and routines in the firm (Lane et al., 2006; Zahra and George, 2002). Recently Lewin et al. (2011) perceive absorptive capacity as a knowledge-based dynamic capability that integrates both internal and external learning routines. Internal learning facilitates new idea generation, enables internal knowledge dissemination and combination, and updates old routines through knowledge application (Nelson and Winter, 1982; Nonaka, 1994; Zollo and Winter, 2002). External learning identifies, acquires, assimilates, transforms, and exploits knowledge from external sources for the purpose of creating new commercial output (Lewin et al., 2011). Lewin et al. (2011) argue that external learning routines are only useful if the acquired knowledge can be transferred back into the firm, and further integrated with internal learning routines for knowledge generation.

The conceptualization of the knowledge-based dynamic capability also reflects exploratory and exploitative learning (Lewin et al., 2011; Lichtenthaler and Lichtenthaler, 2009). Knowledge exploration is carried out by both external learning routines, that recognize and assimilate valuable external new knowledge, and internal learning routines, that create and select new knowledge within firm boundaries (Lewin et al., 2011; March, 1991). Exploratory learning allows firms to experiment with new alternatives, and generate technological change that is necessary for managing challenge in a turbulent environment (Lane et al., 2006; Zollo and Winter, 2002). In contrast, knowledge exploitation is carried out by routines that apply both externally acquired and internally generated knowledge to reconfigure operating routines (Lane et al., 2006; Zollo and Winter, 2002). In line with March (1991), the conceptualization also highlights the necessity of reaching a balance between exploratory and exploitative learning (Lewin et al., 2011; Lichtenthaler and Lichtenthaler, 2009). The cognitive view of firm (Nooteboom, 2009) explains how such a balance can be achieved across different contexts.

According to Nooteboom (2009), 'cognitive distance' exists between individuals to the extent that they have developed different interpretation and understanding of the world along different life paths and in different environments. The primary purpose of a firm is to serve as a cognitive "focusing device" (Nooteboom, 2007, p. 31) that configures the cognitive distance between its members. An optimal cognitive distance is large enough to enable exploratory learning that generates innovative ideas through novel combination of complementary resources, whilst not so distant to preclude necessary mutual understanding needed for exploitative learning to increase efficiency in adaptive process (Nooteboom, 2007). Following this rationale, the essence of the knowledge-based dynamic capability lies in its capacity "to transfer activity to novel contexts that yield opportunities to maintain exploitation, while yielding novel challenges and opportunities for a step-by-step of exploration" (Nooteboom, 2007, p. 49). Through configuring the intelligent capability with a unique combination of internal and external learning routines (Lewin et al., 2011), a firm can generates appropriate cognitive focus for balancing exploratory and exploitative learning (Nooteboom, 2009). The deliberate learning in-turn drives the genesis and evolution of other capabilities and operating routines (Eisenhart and Martin, 2000; Zollo and Winter, 2002).

Drawing upon the conceptualization of the knowledge-based dynamic capability (Lewin et al., 2011; Lichtenthaler and Lichtenthaler, 2009), as well as the 'cognitive theory of the firm' (Nooteboom, 2007, 2009) this study defines learning capability (LC) as a dynamic capability that a manufacturing firm purposefully builds to develop a cognitive focus so as to explore and exploit knowledge resources, within and outside the firm's boundary. Such action is taken in order to modify other dynamic and especially operational capabilities for the purpose of achieving sustained competitive advantages over time. In addition, LC can be viewed as a latent multidimensional construct (Abell et al., 2008); it is not only embedded in higher-order learning routines, but it also depends on governance mechanisms that a firm purposely deploys to influence firm members' engagement in deliberate learning (Foss, 2007). Formal governance mechanisms (such as reward schemes and regulations) and informal mechanisms (such as management styles and organizational cultures) are often applied, simultaneously, to create conducive cognitive focus and contexts which enable learning that modifies other capabilities (Abell et al., 2008; Foss, 2007).

Within the context of manufacturing firms, open communication enables interaction and socialization of individuals; thus it facilitates tacit knowledge generation and externalization during exploratory learning (Carr and Pearson, 1999; Lubit, 2001; Modi and Mabert, 2007). The development and application of an IT system can help to convert tacit knowledge to explicit knowledge and codify the knowledge into repository (e.g. design database) in combination and replication stages of exploitative learning (Hsu, 2006; Renzl, 2008; Taylor, 2006). In addition, sufficient resource, training programs, and incentive schemes, that encourage learning, are essential to support learning within firms (Hsu, 2006; Renzl, 2008; Taylor, 2006). Novel utilizations and new configurations of capabilities require a renewed investment in building these underlying dimensions of LC to build appropriate cognitive focus that enables knowledge exploration and exploitation (Nooteboom, 2009). Therefore, the strategic importance of LC lies in its capacity to create cognitive mechanisms that enable the configuration and improvement of other types of capabilities (both dynamic and operational), in order to create and respond to market changes. In other words, the essential role of LC is to leverage other capabilities to generate higher value. In this sense, the current study highlights the positive moderating effect of LC upon relationships between other capabilities and performance outcomes.

Recent literature shows that investigations into the impact of knowledge-based capabilities upon manufacturing capabilities have received increasing attention. For instance, Pavlou and El Sawy (2011) identified knowledge-based dynamic capabilities, which help to revamp operational capabilities with new knowledge within the NPD context. Attempting to outline possible pathways to capability building, Peng et al. (2008) conceptually linked routines to capabilities and performance; they found a direct impact of innovation capability upon routines responsible for improving processes and quality. Allred et al. (2011) combined evidence derived from cross-sectional survey studies and interviews to support a dynamic collaboration capability as a source of competitive advantage. In their investigation, Liao et al. (2011) addressed the impact of communication on a firm’s knowledge base and its ability to transfer external competence to improve manufacturing system capabilities and market performance. Additionally, the current literature review also reveals proposed moderating effects of learning routines upon relationships between operational routines and manufacturer performance (e.g., Azadegan et al., 2008); relevant empirical evidence is, however, limited in the literature. Further, manufacturing strategy emerges as a result of a coordinated search in the fitness of both innovative product development and supply chain management functions (Adamides and

Pomonis, 2009). In contrast, the capabilities-based studies tend to focus on NPD or supplier management issues, separately. In view of this, the present study takes a routine-based approach to understand capability, and attempts to shed light on the underlying routines of LC, ONPDC and OSIC. Building upon the empirical evidence obtained from the manufacturing contexts, the study concurrently investigated and compared the leveraging effects of LC in configuring and modifying operating routines of ONPDC and OSIC. The following sections define ONPDC and OSIC, and propose two hypotheses to facilitate the investigation of the survey study. The hypotheses also serve as the propositions for the case study.

2.2 Operational NPD capability

A formal stage-gate system, that provides a template for activities, routines, and reviews to be implemented throughout stages of the NPD process, has been widely adopted by manufacturing firms to achieve NPD success (Jespersen, 2012). ONPDC reflects a firm's abilities to technically develop and market new products, as well as administrative activities, at the operational level of NPD processes. This operational capability is embedded in the NPD routines that a firm has developed and practiced over time (Pavlou and El Sawy, 2011). The underlying routines of ONPDC include the fixed process stages and the evaluation criteria at the gates within an established stage-gate-like system (Jespersen, 2012). The routines also include the procedures for, for example, quality function development and cross-functional development that facilitate concurrent engineering (Fixson, 2005). Even though formalized routines define the scope and extent of NPD activities, the mere existence of the routines does not make them valuable, rare, or inimitable resources, which sustain a competitive advantage (Kleinschmidt et al., 2007). Within a dynamic environment, operational routines, without attention to overcoming the barriers to knowledge development, may be inertial rather than beneficial (Benner, 2009). Therefore, ONPDC becomes valuable and rare only when it undergoes firm-specific learning, that is, adjustment for dynamics of a specific industry, market or firm NPD experience.

Accelerating technological dynamics and decreasing product-life-cycles have shifted the strategic focus of manufacturing operations to an efficient NPD process with cost effective design cycles to enable both speed to market and product quality (McNally et al., 2011). The change demands flexibility of product development beyond the bounds of the traditional stage-gate structure (Jespersen, 2012). The literature highlights two broad dimensions of NPD routines to address the challenge: one is employee involvement, another is design simplification and modular product design (e.g., Antonio et al., 2007; Fixson, 2005). Employee involvement routines aim to generate innovative product designs (Antonio et al, 2007; Matsui et al, 2007). The objective can only be fulfilled when exploratory learning routines are in place to maintain sufficient cognitive distance (Nooteboom, 2009). The knowledge exploration enables employees to recognize and assimilate external technological and market knowledge, and integrate it with their own specialist design knowledge to produce new designs that meet the changing market requirements (Berchicci and Tucci, 2010; Lewin et al., 2011). Since the majority of knowledge about routines that permit research and development (R&D) to function is tacit (Nelson and Winter, 1982), the knowledge generation of NPD processes is heterogeneous, ultimately resulting in diverse NPD performance outcomes (Pavlou and El Sawy, 2011). In contrast, design simplification and modular product design need to be leveraged through exploitative learning routines, which combine and replicate design knowledge in modules that are used in different systems to realize multiple functionalities so as to achieve efficiency (Antonio et al, 2007; Matsui et al, 2007; Fynes & Burce, 2005). Cognitive focus is required to create strong mutual understanding for carrying out modular design rapidly without errors (Nooteboom, 2009). ICT facilities, such as a common design database system, are essential for generating the cognitive focus that supports sense-making and learning in NPD, in particular for design simplification and modular product design (Lee et al., 2004). IT applications help capture and formalize the rationale that underpins the design process, and provide a framework where design knowledge can be stored, retrieved and shared (Baxter et al., 2007).

In general, the literature suggests that LC is a highly intelligent capability that enables both knowledge exploration and exploitation based on learning (Azadegan and Wagner, 2011) and keeps the balance between exploratory and exploitative learning (Li et al., 2012). Further, it is responsible for the modification and configuration of the underlining routines of ONPDC, such as fixed process stages and precise sets of evaluation criteria at the project milestone gates (Kleinschmidt et al., 2007). Therefore, LC is perceived as a source of causal ambiguity of unique underlying routines of ONPDC. Thus, to a degree, it provides some explanations for the imperfect imitability and path-dependence of ONPDC. In this vein, a higher LC would be expected to leverage ONPDC to cope with the multitude of uncertainties inherent in a highly dynamic market. Conversely, a lower LC would be expected to lead to less active learning and, hence, result in rigidity and inertia in ONPDC, thereby being less responsive to market changes. This perspective leads to the first hypothesis:

H1: The higher the learning capability, the stronger the association between operational NPD capability and business performance.

2.3 Operational supplier integration capability

In highly dynamic knowledge-based industries (e.g., semiconductors, telecommunications, and consumer electronics) continual innovation appears only possible if a firm reaches beyond its boundaries, since cutting-edge knowledge necessary for innovation tends to be widely dispersed across different firms (Rothaermel et al., 2006). OSIC, thus, reflects a buying firm's abilities to leverage the capacity and capability of its suppliers to improve productivity, quality, and innovation. This operational capability is embedded in two broad dimensions of supplier integration routines, i.e. early supplier involvement as well as supplier selection, evaluation and development (Chin et al., 2006; Modi and Mabert, 2007; Ndubisi et al., 2005; Tan et al., 1999).

Supplier integration links the externally performed work of suppliers into a seamless congruency with the internal work processes of the buying firms (Bowersox et al., 1999). Importantly, supplier integration is sustained by trust, commitment and mutual dependence (Vijayasarathy, 2010). It is primarily built upon relational capital development initiatives such as cross-functional involvement, supplier relationship development, and joint problem solving (Terpend et al., 2008). Also, supplier integration is supported by technological initiatives, such as electronic data interchange and web-based integration systems, as well as application software, such as enterprise resource planning (ERP) systems and supply-chain-optimization (Das et al., 2006). As a hybrid governance mechanism, supplier integration not only reduces the transaction costs of business contracts across internal and external organizational groups (Das et al., 2006), it also leads to shared process development efforts, joint strategic planning exercises, and improved working relationships (Narasimhan et al., 2010). Empirical results suggest that a buying firm's performance is positively affected by buyer-supplier integration approaches in general (Terpend et al., 2008).

Combining knowledge, processes, and organizational relationships, OSIC is perceived as a potential source of vital complementary resources and, thereby, differentiation (Ketchen et al., 2007). Nevertheless, the mere possession of OSIC, while necessary, is not a sufficient condition for competitive advantage (Hunt and Davis, 2008). Knowledge and collaborative relationships associated with the underlying routines of OSIC need to be reconfigured by LC on a continual basis to respond to market changes. Innovation-based manufacturer-supplier relations need to be controlled by certain learning routines. Supplier involvement is facilitated by internal and external communication networks, which carry out exploratory learning to identify and capture product innovativeness. Meanwhile, scanning mechanisms, such as market tracking and benchmarking, integrated in supplier evaluation and selection routines, connect innovative suppliers with the needs of buying firms' internal units (Azadegan et al., 2008). Learning routines assess and merge diverse, complementary skills that reside in different functions and across different organizations; this facet makes OSIC unique and hard to replicate (Allred et al., 2011). Meanwhile, system collaboration recognizes and manages variations in information systems used by multiple supply chain partners, and quickly configures a different system into an integrative model (Kim and Lee, 2010). This exploitative learning approach increases the entire supply chain's responsiveness (Kim and Lee, 2010).

As a firms' learning orientation towards exploitation or exploration bears important implications on its choice of routines in terms of supplier involvement as well as selection and evaluation (Azadegan and Wagner, 2011), an essential role of LC is to facilitate complementary learning with suppliers so as to avoid and/or overcome rigidities in the underlying routines of OSIC (Azadegan et al., 2008). For example, explorative product development firms that follow innovation-focused product strategy could benefit from outsourcing their manufacturing assembly work to a more efficient assembler supplier; whilst exploitative firms that focus more on time-to-market and logistics service operations rely more on design-manufacture suppliers for NPD (Azadegan et al., 2008). Therefore, the second hypothesis highlights the moderating power of LC on leveraging OSIC's degree of influence on business performance, as follows:

H2: The higher the learning capability, the stronger the association between operational supplier integration capability and business performance.

3. Methods

3.1 Empirical context and research design

In order to manage challenges caused by globalization Taiwan's manufacturing firms have shifted their interest in competition and economic growth from prices to product/service innovation (Hsu and Wang, 2008). However there is still limited research addressing how knowledge-based dynamic capabilities, such as LC, are developed to modify NPD and the supplier integration routines of the firms. Thus, the study sought to investigate the research questions within a specific context of Taiwanese electronic manufacturing firms. Given that these firms operate within an open, competitive and dynamic environment, where technological and competitive conditions are subject to rapid changes, the empirical context is suitable for studying dynamic capabilities, such as LC (Helfat et al., 2007; Jespersen, 2012; Zhai et al., 2007).

A mixed methods research framework (Morse, 2003; Yin, 2009) was employed to shed light onto the complex capability related issues through combining sources of evidence from a survey study and a case study. Based on well-developed capability assertions and empirical evidence obtained from manufacturing contexts, the survey study tested hypothesized relationships, and identified "on average" (Carlile and Christensen, 2009: 3) what attributes of LC are associated with significant leveraging power within the empirical context. The case study subsequently investigated contextual conditions for specific routines and performance outcomes that emerged with the patterns matched by the relationships supported by the hypothesis-testing analysis (Yin, 2009). The mixed methods framework was used as a means to strengthen both the reliability and validity of the findings (Yin, 2009), and reveal how the moderating effects resulted in different outcomes in various situations (George and Bennett, 2005); thereby providing guidance for future investigations into contextual factors that influence the strength of LC's moderating effects.

3.2 Survey study

3.2.1 Sample and procedures

During the survey study, data were collected over a period of five months via a mail questionnaire survey to elicit respondents' opinions on the extent to which underlying routines of

LC, ONPDC and OSIC were deployed by the firms, as well as the perceived business performance level at the time of the survey. The questionnaire was pre-tested with forty (40) managerial and professional staff members to evaluate the questionnaire for clarity, bias, ambiguous questions, and relevance to the designated industries and operations of Taiwanese manufacturing firms. Thirty (30) respondents offered valid feedback and advice. The data collection process began after the questionnaire had been finalized, based on the pre-test feedback. The sampling frame included 550 experienced managerial and professional staff members who were knowledgeable about NPD and supplier integration practices in the 241 electronic manufacturing firms listed in the Taiwan Stock Exchange Centre (TSEC) market. In total, 550 survey packages of self-administered surveys were distributed to relevant managerial or professional staff members in the firms. Valid responses (i.e., containing no missing data) were provided by 83 firms. In the process of selecting the valid responses to form the dataset for the analysis, two valid responses were chosen from each of 79 firms; while three valid responses were chosen from each of three very large manufacturing firms (with employee numbers close to 1,000). This approach was adopted to avoid any bias in the data. The response rate of 30.9 percent (170/550) was adequate, according to Sekaran (2000). ANOVA tests were carried out to ensure the 170 cases in the data set were not distorted significantly by the different opinions of specific groups which categorized, respectively, by the control variables of '*firm size*' and '*nature of business*'. The data preparation procedures were also carried out to ensure that the data set was free of extreme outliers, and were reasonably supportive of the assumptions of normality, linearity and homoscedasticity. The responses were considered a good representation of the opinions of the research population, since the majority of the respondents were middle-aged, well-educated, experienced, and knowledgeable about manufacturing operations and management within their firms (see Table 1). Data screening techniques were applied to all variables to make sure that the data complied with the assumptions of normality and linearity.

[Insert Table 1]

3.2.2 Measures

Recent empirical studies on learning (e.g., Hsu, 2006; Lubit, 2001; Modi and Mabert, 2007), NPD (e.g., Ahire and Dreyfus, 2000; Akgün et al., 2010; Antonio et al., 2007), supplier integration (e.g., Chin et al., 2006; Modi and Mabert, 2007; Ndubisi et al., 2005), and performance evaluation (e.g., Antonio et al., 2007; Hsu, 2006; Maiga and Jacobs, 2007; Panuwatwanich et al., 2008; Yeung, 2007) were examined and evaluated so as to provide basic measurable items for operationalizing LC, ONPDC, OSIC and business performance (BP) constructs. Five-point Likert scales were used to measure the operationally-defined variables. Through exploratory factor analysis (EFA) scales were developed with satisfactory reliability, validity, and dimensionality for measuring the level of LC, ONPDC, OSIC and BP (see Appendix A). A factor loading of 0.50 and above was considered significant at the 0.05 level to obtain a power level of 80% with the sample of 170 cases (Hair et al., 1998), and provided evidence of achieving convergent validity (Bagozzi and Yi, 1988). The reliability coefficient values (Cronbach's Alpha (α) > 0.70) reflect a good internal consistency of the scales for the constructs and their factors (Hair et al., 1998). The face validity of the scales was ensured by the conceptualization process, which was based on the thorough literature review and review of initial questionnaire during the pre-test (Neuman, 2003).

In view of the relatively small sample size and exploratory nature of this study, a partial least squares (PLS) approach was used to provide further evidence on the reliability and validity of the scales (Chin, 1998; Peng and Lai, 2012). Bootstrapping tests across 500 bootstrap samples were also performed to assess the stability of the modeling results (Chin, 1998; Peng and Lai, 2012). The results of the measurement model are presented in Table 2 and Appendix A. Individual item reliability was assessed by examining the loading of each item with its respective factors; the rule of thumb was used to accept loadings of 0.70 or more (Hulland, 1999). The test results based on 500 bootstrap samples indicate that 72.4% of the items (21/29) have factor loadings (significant at the 0.01 level) with values equal to or greater than 0.70, as presented in Appendix A. The factor loadings of the other 8 items significant at the 0.01 level with values equal to or greater than 0.50, which are sufficient to support the individual item reliability for the newly developed scales (Chin, 1998). The factor loading values derived from the original sample are slightly higher than those derived from the bootstrap tests (see Appendix A for details). In addition, these results also support convergent validity at the item level (Chin, 1998).

[Insert Table 2]

Composite reliability values are greater than 0.70, indicating good composite reliability at both construct and factor levels according to Chin (1998), as presented in Table 2. Further, the Average Variance Extracted (AVE) is a more conservative reliability measure than composite reliability (Chin, 1998). The AVE values in Table 2 show that the minimum acceptable value of 0.50 (Chin, 1998; Fornell and Bookstein, 1982) are met for most of the constructs and their underlying factors. The only exception is the slightly lower AVE value (0.49) at the construct level of ONPDC. As the AVE values at the factor level of ONPDC are higher than 0.50, the composite reliability values at the construct and factor levels of ONPDC are higher than 0.70; further, the Cronbach's α value of the construct is reasonably high, it is deemed that the ONPDC scale shows sufficient reliability. Tables 2 and 3 show the correlations between the constructs and factors, respectively. The square root of the AVE values are indicated on the diagonal (in the boxes). The diagonal elements of the correlation matrix are greater than the off-diagonal elements. These results indicate that any particular construct shares more variance with its own measures than with other constructs, thereby suggesting adequate discriminant validity of the measurement model (Hulland, 1999). Based on the results, it can be inferred that the constructs differ sufficiently from one another, while discriminant validity was demonstrated (Chin, 1998; Peng and Lai, 2012).

[Insert Table 3]

Within the current context, *learning capability (LC)* is the moderating variable (MV). As presented in Appendix A, the developed scale (α = 0.77) measures LC within the empirical context, in three factors: *IT applications* (LCf1), which reflects the maturity and support level of IT infrastructure and applications; *open communication* (LCf2), which represents routines to share data, information and knowledge, and manage difficulties that impede communication; and *learning support* (LCf3), which refers to organizational mechanisms that facilitate learning.

Operational NPD capability (ONPDC) is an independent variable (IV), and is measured by a two factor scale (α = 0.74) (see Appendix A); *Employee involvement* (ONPDCf1) is concerned with the degree of employee participation and training; *Design simplification* & *modular design* (ONPDCf2) indicates the extent to which component standardization and simplification modular product design are used to improve product design/development.

Operational supplier integration capability (OSIC) is an IV, and as illustrated in Appendix A, its scale (α = 0.71) has two factors. *Supplier evaluation and selection* (OSICf1) measures the degree of the supplier evaluation and selection routines that leverage suppliers' capability. *Supplier involvement* (OSICf2) measures the extent to which supplier involvement improves decision making and the problem solving of design and production processes.

Business performance (BP) is a dependent variable (DV). It is broadly defined to include some of the more prominent financial and non-financial indicators of a firm's competitiveness

(Terpend et al., 2008). Appendix A shows a three-factor scale ($\alpha = 0.85$) for measuring BP within the empirical context. *Business competitiveness* (BPf1) refers to the level of profitability, sales growth and total quality cost reduction, as well as competitive ability, in order to gain or retain new business. *Manufacturing performance* (BPf2) is concerned with engineering change rates, production cycle times, and internal and/or external customer satisfaction. *Process efficiency* (BPf3) reflects the degree of efficiency and effectiveness of operational processes.

Control variables (CVs) include '*firm size*' and '*nature of business*'. The two CVs are selected since they are potential influencing factors within the electronic manufacturing industry context (Terpend et al., 2008). *Firm size* is measured by the number of employees in the firm. The measure of the *nature of business* is concerned with whether the firm is product design only, a mix of design and manufacturing, or product manufacturing only. The measures of the two CVs are listed in Appendix B.

3.3 Case study

As a standalone survey study has a limited ability to adequately explain the real life context (George and Bennett, 2005; Yin, 2009), and given that the manufacturing context and experience of practitioners are critical for increasing the practical relevance of the findings (Barratt et al., 2011), an explanatory case study design was used to investigate the contemporary phenomenon of LC within the natural settings of Taiwanese manufacturing firms. A theoretical sampling approach (Yin, 2009) was used to reveal the insights of LC's leveraging power within the empirical context. The selection of case firms was based on a similar criteria to that applied in the survey study, that is, (1) the firm operated as a private business and had at least 200 employees; and (2) the firm's business scope covered the design and development processes for new electronic products and/or the associated provision of services for management/production functions. Moreover, the study only focused on the case firms' operations carried out by their offices in Taiwan, since the inclusion of worldwide operational sites was beyond the scope of the study and would require additional variables explaining differences in culture, political environments and worker attitudes. As presented in Table 4 the multiple-case study comprised a good mix of case firms focusing on the various segments of the electronic product development supply chain. Following the suggestion of Barratt et al. (2011), the cases were examined within six case firms, in order to capture the complexity of the "real world", while facilitating cognitive processing of the information in a period of four months. The case firms are referred to as firms A, B, C, D, E and F to maintain their anonymity. A total of 19 professionals participated in the interviews, including one project director, eight senior project/product managers, and ten senior R&D/product engineers. Most of the interviews were conducted in the major manufacturing industrial cities of Taiwan (i.e., Taipei, Hsin-Chu and Taichung).

[Insert Table 4]

In each case, two sources of evidence, namely interview transcripts and firm operational performance documentation, were collected for data triangulation purposes. Semi-structured face-to-face interviews were undertaken to provide opportunities for clarifying ambiguous questions and observing the actual environment of the firm being studied (Neuman, 2003). All interviews were recorded and transcribed. An interview guide was developed to maintain the flow and relevance of the interviews, to minimize errors and biases, and to warrant the reliability of data (Yin, 2009). To enable the linkage between data and propositions during data analysis (Yin, 2009), the interview guide design was based on a set of qualitative assessment rubrics, which were developed using the measurement items derived from the factor analysis of the survey study. The case firms' profile, published financial reports, internal newsletters, and other publicly released documents, were obtained to supplement the interview responses. A pattern matching technique was used to strengthen the internal validity of the case study (Yin, 2009).

4. Survey study results

Correlation and regression analyses were employed to analyze the relationships between the constructs and their extracted factors. The correlation analysis showed that the LC, ONPDC and OSIC constructs are positively associated with the BP construct, with Pearson correlation *r* (coefficient of correlation) values of 0.62, 0.58 and 0.56, respectively (significant at $p < 0.01$) (see Table 3). Table 2 presents the correlation analysis results for the factors of LC, ONPDC and OSIC constructs. Most factors are also positively associated with the BP factors. In addition, the associations between the two CVs (i.e., '*firm size*' and '*nature of business*') and the LC, ONPDC, OSIC, and BP constructs and factors are insignificant at either the $p < 0.01$ or $p < 0.05$ level. The results of the correlation analysis provide the basis for undertaking the regression analysis.

Moderated regression analyses with interaction terms (e.g., ONPDC·LC) were performed at both the *construct* and *factor* levels to investigate the respective effect of ONPDC and OSIC on the BP, at different levels of LC (i.e., low, medium, high). In order to minimize multicollinearity, the IVs were centered and the interaction terms were formed by multiplying the two centered variables (Aiken et al., 1991). The 170 cases in the data file satisfied the minimum sample size of 50, for supporting the case-to-IV ratio of 50 to 1 required by the moderated regression analysis with the two IVs (Tabachinick and Fidell, 2001). Multicollinearity is absent from the selected models, where the tolerance values were much higher than 0.1.

4.1 Construct-level analysis

The results of the statistical models, revealing the moderating effect of LC on the relationship between ONPDC, OSIC and BP (i.e., hypotheses H1 and H2) are presented in Table 5. As shown in the left hand side of the table, the Model 3 (that includes the CVs, IVs, MV and the interaction effects) is significant at the $p < 0.01$ level, explaining 65% (indicated by adjusted R^2 value) of the variance in the BP. Model 3 demonstrates that the moderating effect of LC, on the relationship between ONPDC and OSIC with BP, are significant and positive ($p < 0.01$ and $p < 0.05$, respectively). Moreover, the Model 3, which includes the MV for analyzing interaction effects, has a higher R^2 value (i.e., a 0.04 increase) than the Model 2, which excludes them. This outcome demonstrates the degree of importance of the interaction terms ONPDC·LC and OSIC·LC in explaining the relationship. In view of this, the results provide support for hypotheses H1 and H2. Further, given that the change in the R^2 value, due to the inclusion of the interaction effects, is generally small, where a 0.02 change is considered to be an acceptable threshold (Frazier et al., 2004), the 0.04 change in the R^2 value resulting in this study demonstrates a reasonable interaction effect. In addition, the examination of the CVs revealed that '*firm size*' and '*nature of business*' fail to provide significant (at either $p < 0.01$ or $p < 0.05$ level) additional explanation to the variance of the BP in both Models 2 and 3, as presented in Table 5.

[Insert Table 5]

Also, given that the influence upon the hypothesized relationships from the two CVs is insignificant, the hierarchical regression models, excluding the two CVs, were analyzed to reveal the interaction terms' contribution in explaining the variance of BP. As presented in the right hand side of Table 5, the moderated regression model (Model 6), with interaction term ONPDC·LC (corresponding to hypothesis H1), has a larger predicting power over the variance of BP, in comparison with the hierarchical regression model (Model 5 with ONPDC as the IV). This result is indicated by the significant increase in the adjusted R^2 value when the interaction terms were included (0.32 increased to 0.52). Table 5 also presents a significant moderated regression model ($p < 0.05$) (Model 8) which incorporates the interaction term of OSIC·LC (corresponding to hypothesis H2). However, compared with the hierarchical regression model, with OSIC as the IV (Model 7), this moderated regression model only increases the adjusted R^2 value from 0.31 to 0.32.

To further investigate the respective effect of ONPDC and OSIC on BP at different levels of LC, the values of LC were chosen to be one standard deviation below the mean (LC low = -0.30), at the mean (LC medium = 0.00), and one standard deviation above the mean (LC high = 0.30), following Aiken et al.'s (1991) recommendation. The hierarchical regression lines were then generated by substituting these values (-0.30, 0.00, 0.30) into the moderated regression models, with the interaction terms (i.e., ONPDC·LC and OSIC·LC). As a result of this computation, three hierarchical moderated regression equations were produced (Fig. 1), where the influence of LC on the relationships between the ONPDC and BP constructs was revealed. The statistical significance of the slopes of these regression equations were also analyzed and established, following the analytical approaches suggested by Aiken et al. (1991). The hierarchical regression models, represented by the three linear lines shown in Fig. 1, indicate a significant ($p < 0.05$) positive regression of BP on ONPDC at all three levels of LC. The figure also lends support for the proposition that the higher the LC level, the steeper the slope, suggesting that LC has a positive moderating effect on ONPDC's contribution to BP. This finding authenticates hypothesis H1, that the higher the LC, the stronger the association between ONPDC and BP. Through a similar analysis the moderated regression equations were derived and illustrated in Fig. 2, which shows a significant ($p < 0.05$) positive regression of BP on OSIC for all three levels of LC. This analysis suggests that the LC construct has a positive, whilst weak, influence on OSIC's contribution to BP. However, individual factors within the LC construct may have stronger leveraging power than others, thus requiring further investigation on hypothesis H2.

[Insert Fig. 1 and Fig. 2]

4.2 Factor-level analysis

The factor-level hierarchical moderated regression analysis, with post-hoc probing of the significant moderating effects, was conducted to provide further in-depth verification of the construct level interaction effects (Holmbeck, 2002). The analysis also meant to identify LC factors of stronger moderating effect; ONPDC, in particular OSIC factors were comparatively more sensitive to the effect; and the performance indicators (reflected by specific BP factors) were strongly associated with the moderating effect. Fig. 3 and Fig. 4 show the factor level regression models, with the larger predicting power (reflected by adjusted R^2 value), corresponding to hypotheses H1 and H2, respectively. The analysis demonstrates a significant ($p < 0.01$) positive regression of BPf1 (*business competitiveness*) on ONPDCf2 (*design simplification and modular design*) for all three levels of LCf1 (*IT applications*). As presented in Fig. 3, when the LCf1 is high, there is a positive leveraging power of ONPDCf2 on BPf1, whilst there is no evident impact from a medium level of the LCf1 on ONPDCf2 with BPf1. Adversely, when LCf1 is low, there appears to be a negative relationship between ONPDCf2 and BPf1. The moderated regression models displayed in Fig. 4 indicate a significant ($p < 0.01$) positive regression of BPf on OSICf1 (*supplier evaluation and selection*) for all three levels of LCf1.

[Insert Fig. 3 and Fig. 4]

Tables 6 and 7 present the significant regression models corresponding to hypotheses H1 and H2, respectively. As shown in Table 6, the models identified the significant leveraging power of both IT applications and open communication on design simplification and modular design for sustaining business competitiveness (BPf1), as reflected by sales growth, profitability, total quality cost reduction and competitive ability improvement. Meanwhile, the analysis also demonstrated that the application of IT facilitates employee involvement in achieving better manufacturing performance (BPf2), e.g. improved customer retention, product cycle time and decreasing engineering changes rates. The findings in Table 7 imply that IT applications not only empower supplier evaluation and selection to improve business competitiveness, but also enable supplier involvement to improve manufacturing performance. In summary, the analysis identified that IT applications play the most active role in leveraging operational routines for sustaining business competitiveness (BPf1).

[Insert Tables 6 and 7]

5. Case study results

The survey study supports hypotheses H1 and H2; however, the study provides a limited explanation for the context where the proposed relationships emerge. The two control variables, '*firm size*' and '*nature of business*', failed to provide significant additional explanation for the variance of BP. In view of this, the case study was undertaken to increase the reliability and validity of the findings and, in particular, to investigate the real-life research context. The case study data analysis procedure consisted of two key steps: within-case and cross-case analyses (Yin, 2009). The results of both the within- and the cross-case analyses were presented to the interviewees of the cases' firms for validation. At the same time, further phenomena associated with the findings (e.g., patterns) were collected.

5.1 Within-case analysis

The within-case analysis evaluated the collected data, and reported the findings of each individual case. The findings provide insightful events and phenomena that reflect how underlying attributes of the factors and constructs of the survey study were perceived within the empirical context of a real-life setting. This outcome is presented in the form of a qualitative rating of such factors and constructs. By using a descriptive coding, each piece of evidence (in a documentary format) was assigned a reference number, while its content was coded so that it could be classified into relevant factors (Miles and Huberman, 1989). The coded interview contents were documented in an evidentiary-based manner, in accordance with Miles and Huberman's (1989) tabular approach.

Thus, a matrix of categories was created, representing the factors of the survey study, with the evidence placed within such categories. The evidence was, subsequently, evaluated through a systematic rating procedure in which each of the factors was classified, based on its corresponding evidence, into one of the following rating indicators: high, medium, or low. To ensure the reliability and consistency of the rating, a set of qualitative assessment matrices was developed to serve as the criteria for classifying the factors into one of the above three indicators. To match a factor with a particular rating indicator, the evidence needed to demonstrate a close match to the details of a statement within the relevant criteria. Once the individual factors had been rated, they were qualitatively aggregated to represent the overall rating of their respective construct. The qualitative assessment rubric for factors OSICf1, BPf1 and the associated interaction term OSICf1·LCf1, are presented in Appendix C, as examples.

Table 8 summarizes the within-case analysis results, and presents, for each case, the rating levels determined for the four constructs (OSIC, ONPDC, LC and BP), and their related factors, derived from the qualitative findings. The results also demonstrate the reliability and validity of the rated factors in representing the constructs of the survey study. Most of the factors within each construct appear to be consistently and positively correlated across all of the participating firms. Within the ONPDC and OSIC constructs, most factors appeared to be highly correlated in all cases. Further, most of the factors within the BP and LC constructs appeared to be well correlated with one another, particularly those in the cases A, C, D and F. In other cases, at least two out of three factors were highly correlated. Only the result for the LC construct for firm B showed a lack of correlation between the factors. Additionally, the interviews revealed a special contextual phenomenon of case B, which appeared to be associated with the only anomaly that occurred during the within-case analysis. Generally speaking, the model factors proved to be adequately reliable and valid in capturing the qualitative rating level of the constructs, which provided further evidence of the robustness of the model factor structure uncovered by the survey study.

[Insert Table 8]

5.2 Cross-case analysis

The purpose of the subsequent cross-case analysis was to reveal insightful information about how specific routines and performance outcomes emerged with the pattern of interaction relationships, and which contextual conditions potentially influenced the strength of the moderating effects. A pattern matching technique (Yin, 2009) was used to link the collected data to the theoretical propositions. The patterns of qualitatively categorized circumstances were compared with those predicted patterns, supported by the regression models, as detailed in Table 9. According to Yin (2009), the actual pattern-matching procedure did not involve precise comparisons or quantitative/statistical criteria to judge the pattern. Instead, the procedure dealt only with either gross matches or mismatches; in other words, the postulation of very subtle patterns was avoided. During the analysis, patterns were developed using the codified *high*, *medium* and *low* values, following the study by Nicholson and Kiel (2007); the associated descriptions were tabulated for the model constructs (i.e., LC, ONPDC, OSIC and BP).

[Insert Table 9]

The cross-case analysis results, presented in Table 10, highlight: 1) the qualitative rating for the constructs (i.e., ONPDC, OSIC, LC and BP) derived from the study within each case firm; and 2) the predicted patterns (supported by the regression analysis, as shown in Table 9) matched by findings obtained from each case firm. As the table illustrates, the relationship patterns for the rated constructs in case firms A, C and D show a perfect match to the predicted patterns of *PP_ONPDC·LCha* and *PP_OSIC·LCha*, which are supported by the regression analysis, as presented in Table 9. At case firms A, C and D, the level of ONPDC (high) and OSIC (high) indicates a strong correlation with the level of BP (high). As predicted, the level of LC (high) appears to serve a moderating role, which, in turn, leverages the level of BP (high). A similar predicted pattern can be seen in firm F; the only difference is that all the constructs have a medium level rating, which emulates the predicted patterns of *PP_ONPDC·LCmb* and *PP_OSIC·LCmb*. In addition, the results of the case study for firm E show that the relationships between both ONPDC (medium) and OSIC (medium) with BP (medium) seem to be moderated by LC (High), as predicted by the patterns of *PP_ONPDC·LChb* and *PP_OSIC·LChb*. Similarly, the relationships between all the rated constructs for firm B seem to match the predict patterns of *PP_ONPDC·LCma* and *PP_OSIC·LCma*. Therefore, the results from the pattern matching analysis lent support to the validity of the findings from the survey study, in particular, the moderating role of LC on the relationships between ONPDC and OSIC with BP.

[Insert Table 10]

5.3 Case study discussion

The insights extracted from the interviews support the finding that LC is an essential capability, and that it is responsible for leveraging the operating routines of product development and supplier management. In terms of NPD, the interviews revealed that high-level learning routines helped to shorten product development time and reduce potential quality deficiencies. This improved the case firms' capabilities in managing challenges in a constantly changing market. The interviewees perceived that learning from industrial partners (e.g., major suppliers, customers and research institutes) was essential, especially for design simplification and modular design, since high-level learning routines help to acquire an extensive array of software and hardware know-how, in time. Resource and knowledge sharing centres were also used by most case firms to engage employees in learning, particularly, exploratory learning. Further, IT systems were widely applied to retain and share design know-how and past lessons learnt, which were subsequently codified into guidelines for stimulating more innovative design ideas and avoiding design flaws. An interviewee provides some insights about the exploitative learning:

> "…Our firm's intranet-based platform monitors the internal (e.g., operations) and external (e.g., suppliers) performance indicators generated from a variety of product development stages…incoming and outgoing reject rates, corrective action reports, etc. …This integrated information system helps us to carry out a wide range of routines, such as updating standard operation procedures, and recording lessons learned…The system increases our confidence in the continual improvement of [the firm's] capabilities to get new business."

The interviews also revealed that the IT system and the digitalised documents were a convenience for providing confidential design information disclosure (e.g., to competitors). Some products were of a unique design and customer-made features and, hence, required strict compliance with intellectual property restrictions. Under these special circumstances the case firms focused on internal learning routines, through encouraging employee interaction and offering incentives for new ideas generation and, at the same time, strengthening their internal network security. For example, in order to effectively handle confidentiality issues, case firm B adopted a more traditional mentoring program to train and educate their new engineers (an internal exploitative learning approach) (Kale and Singh, 2007), rather than utilizing IT supported learning platforms/centers to circulate resources and knowledge. It appeared that the special contextual conditions of case firm B gave rise to this anomaly during the within-case analysis.

Congruent with Pentland and Feldman's (2005) findings, the current case study found that case firms developed artifacts (such as rules, standards, check lists, guidelines and databases) through knowledge codification. The exploitative learning approach was used to create and maintain operating routines to achieve the desired performance. In the meantime, exploratory learning was carried out to update the artifacts so as to prevent inertia in the ONPDC routines that could be caused by static artifacts. Moreover, the interviewees also acknowledged the difficulties in evaluating the effects of learning strategies that involved the sharing of tacit knowledge. In general, however, the findings revealed that LC provided cognitive mechanisms that continually reconfigured and, to a large degree, drove the evolution of the underlying routines of ONPDC to meet the needs of the constantly changing market.

The interview participants acknowledged that competitiveness and performance could be improved by integrating learning with the supplier integration strategies. Both exploitative learning, such as assessment training and exploratory learning which encouraged innovation, were mentioned by the interviewees. It appeared that e-forum databases and e-learning were applied by the case firms to support both exploratory and exploitative learning. A senior product manager revealed that IT helped to build an essential learning platform. Indeed, within the research context of Taiwanese electronic manufacturing firms, ERP systems were widely adopted to integrate internal and external management information (embracing finance, design, manufacturing, sales and service, etc.). The development of ERP systems had increasingly extended enterprise functionality in crossing firm boundaries to enhance flexibility for meeting the ever-changing supply chain needs. Further, most case firms made an effort to provide greater support for IT infrastructure, systems and applications, so as to create a learning environment for supplier integration activities.

The study also found that the case firms had unique evolutionary paths; they also differed in resource endowments and managerial capacity. In addition, contextual conditions, including ‘hard conditions’ (such as the structure of a supply chain) and ‘soft conditions’ (such as the organizational culture of partnering firms within the chain) also influenced how LC was developed to drive the evolution of OSIC in a particular case firm. According to several interviewees, customer design-focused and project-oriented work increased difficulties when resources and knowledge needed to be shared or codified between the buyer and supplier/s. For example, an interviewee from case firm B noted that:

> "…Some projects are one-off projects. This means that a proportion of the resources and knowledge created by such a project may not be shared by other projects, since learning outcomes do not seem to have much impact."

In addition, the contingency was also said to increase when tacit knowledge was heavily involved. Further, organizational culture was perceived as a critical factor for keeping sufficient cognitive distance, as required by exploratory learning and innovation. For instance, an interviewee from case firm E commented:

> "…Our firm provides design, manufacturing and customer-oriented technical support. The service specifications of each project have some unique features. The accelerating technological development in network storage solution means that we need to depend on employees' experience, especially their creativity, to cope with changing market needs…Both IT infrastructure and learning culture are important for success. However, cultivating a culture that encourages learning and innovation is a particularly difficult job."

6. Discussions and conclusions

This study was motivated to demonstrate the leveraging power of LC upon essential operational manufacturing capabilities (i.e., ONPDC and OSIC). The study also sought to identify high-level learning routines that can be manipulated by managers and practitioners, so as to reconfigure underlying routines of ONPDC and OSIC for the purpose of effecting superior performance within a turbulent environment, over time. A mixed methods research framework (that combined evidence derived from a survey study and a multiple case study) was used to fulfill the research objective. Recent assertions about the knowledge-based dynamic capability (Lewin et al., 2011; Lichtenthaler and Lichtenthaler, 2009; Nooteboom, 2009) are congruent with the survey study in its support of LC. This was particularly so with this dynamic capability being able to leverage the two operational capabilities to effect better business performance.

Indeed, the regression analyses at both the construct and factor levels demonstrated the positive moderating effects of LC on the contribution of both operational capabilities (i.e., ONPDC and OSIC) to performance outcomes. Furthermore, the analysis at the factor level highlighted that IT applications significantly leverage design simplification and modular design, as well as supplier evaluation and selection, to improve business competitiveness. This outcome is indicated by a number of bottom line indicators, such as profitability increase, total quality cost reduction, and sales growth. In addition, the comparison of the leveraging power of LC within the context of NPD, and that of supplier integration, reveals a stronger moderating effect of the learning routines upon ONPDC.

The case study provided important insights that explain how LC modifies and reconfigures underlying routines of ONPDC and OSIC, so that firms can respond to the dynamic changes in the market. The interviews revealed that the manufacturing firms developed complex complementarities between the internal and external learning routines to form an appropriate cognitive distance, which enabled exploratory and exploitative learning. Additionally, the case study found that the history of the case firms decided, to a large degree, the underlying learning routines of their LC. The contextual factors also influenced the complex social mechanisms that enabled the deliberate learning of the firms. Causal ambiguity of LC was also evident during the interviews, where some experienced managers had difficulty clearly articulating the performance implications of certain learning routines that deal intensively with tacit knowledge. The findings imply that LC in the case firms was idiosyncratic; it was also hard to imitate due to the path dependence, social complexity and causal ambiguity.

The interviews revealed that the underlying routines of ONPDC and OSIC of the case firms were constantly reconfigured and modified by higher-level learning routines. While some firms depended primarily on internal innovation to generate new designs that differentiated their products and adopted exploratory learning strategies; others tended to leverage customer and supplier design advantage in NPD and used exploitative learning strategies. The findings suggest that the leveraging power of LC created firm specific ONPNC and OSIC, which became valuable resources that effected superior performance outcomes. Furthermore, NPD appeared to involve higher levels of knowledge exploration that relied much more on the cognitive mechanisms provided by LC to generate innovation; in contrast supplier integration routines depended on LC primarily for the exploitation of knowledge in the supply chain. These findings explain the different moderating effects of LC upon ONPDC and OSIC, as identified by the regression analyses.

Additionally, the case study also uncovered the contextual factors that affected how a particular case firm developed its LC through various combinations of knowledge exploration and exploitation strategies. These factors included the supply chain structure, the organizational culture of the firm and its partners, the project's nature, and the product and service types, especially the tacitness of production and services knowledge. In the real world industrial situation, these factor also affected the degree to which the case firms' LC modified ONPDC and OSIC. The results, derived from the mixed methods study, suggest that certain high-level learning routines of LC can be used to modify and configure the underlying routines of ONPDC and OSIC. Further, it is apparent that the approaches are context-specific.

The findings imply that manufacturing firms need to place an emphasis on encouraging employees to engage in learning. A wide range of arrangements were adopted by the case firms to provide good examples of effective learning mechanisms, for example: assigning a chief knowledge officer and a dedicated unit to support learning across the entire firm; making arrangement with major suppliers, customers, and research institutes to share technical and managerial know-how; using performance indicators to assess the learning performance of each employee and provide incentives; offering strong support to the IT system; and updating frequently knowledge repository. Furthermore, since LC is an intelligent high level capability, its underlying routines should be embedded into NPD and supplier integration routines to effect reconfiguration and evolution. In other words, learning programs should be promoted and designed as an integral part of NPD and supplier integration plans within a firm's overall strategic management consideration.

7. Future studies

The mixed methods study revealed the possibility that the issues surrounding the leveraging power of LC were more multifaceted than initially proposed. The study also identified the need to develop more convincing and robust explanations of the social processes being investigated. Despite its contributions, obtained from a rigorous two-stage sequential mixed methods research design, the findings from the present studies could be strengthened in a number of ways in order to advance the theory building cycle (Carlile and Christensen, 2009). Firstly, further studies could be undertaken to investigate the contextual conditions that influence the strength of the leveraging power of LC. Through observation and measurement of the phenomena, as well as the categorization of the circumstances within the real workplace context, future studies could seek to derive causal statements relating to the influence of the contextual factors (e.g., organizational culture, supply chain structure, project styles, and even product types) on LC's moderating effects. A deductive approach could be used to test the casual propositions. Secondly, a longitudinal study could be conducted and, potentially, a system dynamics model formulated to reveal how the underlying routines of LC drive operational capabilities, over time. Thirdly, based on the findings of the survey and case studies, a capability-based learning benchmarking system could be developed. This approach would help firms to align LC with the desired business objectives they intend to achieve through undertaking LC self-assessment. Such a benchmarking system could also help to promote best learning practices within the industry. These proposed studies have the potential to contribute to the continuous advancement of the body of knowledge addressing knowledge-based dynamic capabilities.

References

Abell, P., Felin, T., Foss, N., 2008. Building micro-foundations for the routines, capabilities, and performance links. Managerial and Decision Economics 29 (6), 489-502.

Adamides, E.D., Pomonis, N., 2009. The co-evolution of product, production and supply chain decisions, and the emergence of manufacturing strategy. International Journal of Production Economics 121 (2), 301-312.

Ahire, S.L., Dreyfus, P., 2000. The impact of design management and process management on quality: An empirical investigation. Journal of Operations Management 18 (5), 549-575.

Aiken, L.S., West, S.G., Reno, R.R., 1991. Multiple Regression: Testing and Interpreting Interactions. Sage Publications, Inc, Newbury Park, Calif.

Akgün, A.E., Keskin, H., Byrne, J.C., 2010. Procedural justice climate in new product development teams: Antecedents and consequences. Journal of Product Innovation Management 27 (7), 1096–1111.

Allred, C.R., Fawcett, S.E., Wallin, C., Magnan, G.M., 2011. A dynamic collaboration capability as a source of competitive advantage. Decision Sciences 47 (1), 129-161.

Antonio, K.W.L., Yam, R.C.M., Tang, E., 2007. The impacts of product modularity on competitive capabilities and performance: An empirical study. International Journal of Production Economics 105 (1), 1-20.

Azadegan, A., Dooley, K.J., Carter, P.L., Carter, J.R., 2008. Supplier innovativeness and the role of interorganizational learning in enhancing manufacturer capabilities. Journal of Supply Chain Management 44 (4), 14-35.

Azadegan, A., Wagner, S.M., 2011. Industrial upgrading, exploitative innovations and explorative innovations. International Journal of Production Economics 130 (1), 54-65.

Bagozzi, R., Yi, Y., 1988. On the evaluative of structural equation models. Journal of the Academy of Marketing Science 14 (3), 74-94.

Barratt, M., Choi, T.Y., Li, M., 2011. Qualitative case studies in operations management: Trends, research outcomes, and future research implications. Journal of Operations Management 29 (4), 329-342.

Baxter, D., Gao, J., Case, K., Harding, J., Young, B., Cochrane, S., Dani, S., 2007. An engineering design knowledge reuse methodology using process modelling. Journal of Research Engineering Design 18 (1), 37-48.

Benner, M.J., 2009. Dynamic or static capabilities? Process management practices and response to technological change. Journal of Product Innovation Management 26 (5), 473-486.

Berchicci, L., Tucci, C.L., 2010. There is more to market learning than gathering good information: The role of shared team values in radical product definition. Journal of Product Innovation Management 27 (7), 972-990.

Bowersox, D.J., Closs, D.J., Stank, T.P., 1999. 21st Century Logistics: Making Supply Chain Integration a Reality. Council of Logistics Management, Oak Brook, IL.

Carlile, P.R., Christensen, C.M. 2009. The Cycles of Theory Building in Management Research. Technology and Operations Management, Harvard Business School, <http://hbswk.hbs.edu/cgi-bin/print?id=5422>, (2 August 2009)

Carr, A.S., Pearson, J.N., 1999. Strategically managed buyer-supplier relationships and performance outcomes. Journal of Operations Management 17 (5), 497-519.

Chin, K.S., Yeung, I.K., Pun, K.F., 2006. Development of an assessment system for supplier quality management. International Journal of Quality & Reliability Management 23 (7), 743-765.

Chin, W.W. 1998. The partial least squares approach to structural equation modeling. Modern Methods for Business Research, Marcoulides, G.A., ed., Lawrence Brlbaum Associates, Mahwah, NJ, 295–336.

Cohen, W., Levinthal, D., 1990. Aborptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly 35, 128-152.

Das, A., Narasimhan, R., Talluri, S., 2006. Supplier integration—Finding an optimal configuration. Journal of Operations Management 24 (5), 563-582.

da Silva Gonçalves Zangiski, M. A., Pinheiro de Lima, E. and Gouvea da Costa, S. E., 2013. Organizational competence building and development: Contributions to operations management. International Journal of Production Economics, DOI: 10.1016/j.ijpe.2013.01.021 (Article in Press).

Eisenhart, K.M., Martin, J.A., 2000. Dynamic capabilities: What are they? Strategic Management Journal 21 (10/11), 1105-1121.

Fixson, S.K., 2005. Product architecture assessment: A tool to link product, process, and supply chain design decisions. Journal of Operations Management 23 (3-4), 345-369.

Fornell, C., Bookstein, F.L., 1982. Two structural equation models: Lisrel and PLS applied to consumer exit-voice theory. Journal of Marketing Research 19 (4), 440-452.

Foss, N.J., 2007. The emerging knowledge governance approach: Challenges and characteristics. Organization 14 (1), 29-52.

Frazier, P.A., Tix, A.P., Barron, K.E., 2004. Testing moderator and mediator effects in counselling psychology research. Journal of Counselling Psychology 51 (1), 115-134.

George, A.L., Bennett, A., 2005. Case Studies and Theory Development in the Social Sciences. MIT Press, Cambridge.

Hair, J.F., Anderson, R.E., Tatham, R.L., Black, W.C., 1998. Multivariate Data Analysis. Prentice-Hall International, Inc., Upper Saddle River, NJ.

Helfat, C.E., Finkelstein, S., Mitchell, W., Peteraf, M.A., Singh, H., Teece, D.J., Winter, S.G., 2007. Dynamic Capabilities: Understanding Strategic Change in Organizations. Blackwell Publishing, Malden, MA, USA.

Holmbeck, G.N., 2002. Post-hoc probing of significant moderational and mediational effects in studies pediatric populations. Society of Pediatric Psychology 27 (1), 87-96.

Hsu, I.C., 2006. Enhancing employee tendencies to share knowledge- case studies of nine companies in Taiwan. International Journal of Information Management 26, 326-338.

Hsu, I.C., Wang, Y.S., 2008. A model of intraorganizational knowledge sharing: Development and initial test. Journal of Global Information Management 16 (3), 45-47.

Hull, C.E., Covin, J.G., 2010. Learning capability, technological parity, and innovation mode use. Journal of Product Innovation Management 27 (1), 97-114.

Hulland, J., 1999. Use of Partial Least Squares (PLS) in strategic management research: A review of four recent studies. Strategic Management Journal 20 (2), 195-204.

Hunt, S.D., Davis, D.F., 2008. Grounding supply chain management in resource-advantage theory. Journal of Supply Chain Management 44 (1), 10-21.

Jespersen, K.R., 2012. Stage-to-Stage information dependency in the NPD process: Effective learning or a potential entrapment of NPD gates? Journal of Product Innovation Management 29 (2), 257-274.

Kale, P., Singh, H., 2007. Building firm capabilities through learning: the role of the alliance learning process in alliance capability and firm-level alliance success. Strategic Management Journal 28 (10), 981-1000.

Ketchen, D.J., Hult, G.T.M., Slater, S.F., 2007. Toward greater understanding of market orientation and the resource-based view. Strategic Management Journal 28 (9), 961-964.

Kim, D., Lee, R.P., 2010. Systems collaboration and strategic collaboration: Their impacts on supply chain responsiveness and market performance. Decision Sciences 41 (4), 955-981.

Kleinschmidt, E.J., de Brentani, U., Salomo, S., 2007. Performance of global new product development programs: A resource-based view. Journal of Product Innovation Management 24 (5), 419-441.

Kyläheiko, K., Sandström, J., Virkkunen, V., 2002. Dynamic capability view in terms of real options. International Journal of Production Economics 80 (1), 65-83.

Lane, P.J., Koka, B.R., Pathak, S., 2006. The reification of absorptive capacity: A critical review and rejuvenation of the construct. The Academy of Management Review 31 (4), 833-863.

Lee, C.K.M., Lau, H.C.W., Yu, K.M., Fung, R.Y.K., 2004. Development of a dynamic data interchange scheme to support product design in agile manufacturing. International Journal of Production Economics 87 (3), 295-308.

Lewin, A.Y., Massini, S., Peeters, C., 2011. Microfoundations of internal and external absorptive capacity routines. Organization Science 22 (1), 81-98.

Liao, Y., Liao, K., Tu, Q., Vonderembse, M., 2011. A mechanism for external competence transfer to improve manufacturing system capabilities and market performance. International Journal of Production Economics 132 (1), 68-78.

Li, Y., Wei, Z., Zhao, J., Zhang, C. and Liu, Y. 2012. Ambidextrous organizational learning, environmental munificence and new product performance: Moderating effect of managerial ties in china. International Journal of Production Economics, DOI: 10.1016/j.ijpe.2012.11.008 (Article in press).

Lichtenthaler, U., Lichtenthaler, E., 2009. A capability-based framework for open innovation: Complementing absorptive capacity. Journal of Management Studies 46 (8), 1315-1338.

Lubit, R., 2001. Tacit knowledge and knowledge management: The keys to sustainable competitive advantage. Journal of Organizational Dynamics 29 (4), 164-178.

Maiga, A.S., Jacobs, F.A., 2007. Activity-based cost management and manufacturing, operational and financial performance: A structural equation modeling approach. Journal of Advances in Management Accounting 16, 217-260.

March, J.G., 1991. Exploration and exploitation in organizational learning. Organization Science 2 (1), 71-88.

Marsh, S.J., Stock, G.N., 2006. Creating dynamic capability: The role of intertemporal integration, knowledge retention, and interpretation. Journal of Product Innovation Management 23 (5), 422-436.

McNally, R.C., Akdeniz, M.B., Calantone, R.J., 2011. New product development processes and new product profitability: Exploring the mediating role of speed to market and product quality. Journal of Product Innovation Management 28 (1), 63-77.

Miles, M.B., Huberman, A.M., 1989. Qualitative Data Analysis: A Source Book of New Methods. SAGE Publications, Newbury Park.

Modi, S.B., Mabert, V.A., 2007. Supplier development: Improving supplier performance through knowledge transfer. Journal of Operations Management 25 (1), 42-64.

Morse, J.M., 2003. Principles of mixed methods and multimethod research design. Handbook of Mixed Methods in Social & Behavioral Research. In: Teddlie, C., Tashakkori, A., (Eds.), SAGE Publications. London, 189-208.

Narasimhan, R., Swink, M., Viswanathan, S., 2010. On decisions for integration implementation: An examination of complementarities between product-process technology integration and supply chain integration. Decision Sciences 41 (2), 355-372.

Ndubisi, N.O., Jantan, M., Hing, L.C., Ayub, M.S., 2005. Supply selection and management strategies and manufacturing flexibility. Journal of Enterprise Information Management 18 (3), 330-349.

Nelson, R.R., Winter, S.G., 1982. An Evolutionary Theory of Economic Change. Harvard University Press, Cambridge.

Neuman, W.L., 2003. Social Research Methods: Qualitative and Quantitative Approaches. Allyn and Bacon, Boston.

Nicholson, G.J., Kiel, G.C., 2007. Can directors impact performance? A case-based test of three theories of corporate governance. Corporate Governance 15 (4), 585-608.

Nonaka, I., 1994. A dynamic theory of organizational knowlege creation. Organization Science 5 (1), 14-37.

Nooteboom, B., 2007. Organization, evolution, cognition and dynamic capabilities. ICFAI Journal of Managerial Economics 5 (4), 31-55.

Nooteboom, B., 2009. A Cognitive Theory of the Firm : Learning, Governance and Dynamic Capabilities. Edward Elgar, Cheltenham, UK.

Panuwatwanich, K., Stewart, R.A., Mohamed, S., 2008. The role of climate for innovation in enhancing business performance: The case of design firms. Engineering, Construction and Architectural Management 15 (5), 407-422.

Pavlou, P.A., El Sawy, O.A., 2011. Understanding the elusive black box of dynamic capabilities. Decision Sciences 42 (1), 239-273.

Peng, D.X., Lai, F., 2012. Using partial least squares in operations management research: A practical guideline and summary of past research. Journal of Operations Management 30 (6), 467-480.

Peng, D.X., Schroeder, R.G., Shah, R., 2008. Linking routines to operations capabilities: A new perspective Journal of Operations Management 26 (6), 730-748.

Pentland, B.T., Feldman, M.S., 2005. Organizational routines as a unit of anlaysis. Industrial and Corporate Change 14 (5), 793-815.

Renzl, B., 2008. Trust in management and knowledge sharing: The mediating effects of fear and knowledge documentation. International Journal of Management Science 36 (2), 206-220.

Rothaermel, F.T., Hitt, M.A., Jobe, L.A., 2006. Balancing vertical integration and strategic outsourcing: effects on product portfolio, product success, and firm performance. Strategic Management Journal 27 (11), 1057-1080.

Sekaran, U., 2000. Research Methods for Business - A Skill-Building Approach. John Wiley & Sons, Inc., Chichester.

Tabachinick, B.G., Fidell, L.S., 2001. Using Multivariate Statistics. Allyn and Bacon, Boston.

Tan, K.C., Kannan, V.R., Handfield, R.B., Ghosh, S., 1999. Supply chain management: An empirical study of its impact on performance. International Journal of Operation & Production Management 19 (10), 1034-1052.

Taylor, E.Z., 2006. The effect of incentives on knowledge sharing in computer-mediated communication: An experimental investigation. Journal of Information Systems 20 (1), 103-116.

Teece, D.J., 2007. Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. Strategic Management Journal 28 (13), 1319-1350.

Teece, D.J., Pisano, G., Shuen, A., 1997. Dynamic capabilities and strategic management. Strategic Management Journal 18 (7), 509-533.

Terpend, R., Tyler, B.B., Krause, D.R., Handfield, R.B., 2008. Buyer-supplier relationships: Derived value over two decades. Journal of Supply Chain Management 44 (2), 28-55.

Vijayasarathy, L.R., 2010. Supply integration: An investigation of its multi-dimensionality and relational antecedents. International Journal of Production Economics 124 (2), 489-505.

Winter, S.G., 2003. Understanding dynamic capabilities. Strategic Management Journal 24 (10), 991-995.

Yeung, A.C., 2007. Strategic supply management, quality initiatives, and organizational performance. Journal of Operations Management 26 (4), 490-502.

Yin, R.K., 2009. Case study research : Design and methods. Sage Publications, Thousand Oaks, Calif.

Zahra, S.A., George, G., 2002. Absorptive capacity: A review, reconceptualization, and extension. Academy of Management Review 27 (2), 185-203.

Zhai, E., Shi, Y., Gregory, M., 2007. The growth and capability development of electronics manufacturing service (EMS) companies. International Journal of Production Economics 107 (1), 1-19.

Zollo, M., Winter, S.G., 2002. Deliberate learning and the evolution of dynamic capabilities. Organization Science 13 (3), 339-351.

Table 1

Respondent profile summary of the survey study.

Category	Frequency	Percentage
Age		
More than 31 years old	124	73%
Educational background		
A bachelor degree or higher	141	83%
Position		
Executives	31	18%
Managers	68	40%
Senior engineers	71	42%
industry experience		
More than 4 years	127	75%
Firm operation year		
More than 6 Years	65	78%
Firm categories		
Product design and manufacturing function	60	72%
Product manufacturing function	13	16%
Product design function	10	12%
Firmscale		
Multinational	61	74%
National and/or regional	22	26%
No. of Employee		
≤ 200	12	15%
201 - 500	46	55%
> 500	25	30%

Table 2

Descriptive statistics, correlations and discriminant validity of the constructs.

Construct	Factors	Number of Item	Item loading range (derived from original sample)[b]	Composite reliability	Communality (AVE)	MAX	MIN	Mean	S.D.	1	2	3	4	5	6	7	8	9	10
	Nature of business[a]					3	1	2.81	.53	.03	.04	.00	-.06	-.07	.00	-.05	-.06	-.05	-.07
	Employee number[a]					8	3	5.11	1.11	.08	-.05	-.03	.01	.03	.04	.13	.07	-.03	.01
LC				0.78	0.52														
	1. LCf1: IT applications	3	0.70-0.90	0.70	0.57	4.00	2.67	3.26	.35	**.75**									
	2. LCf2: Open communication	3	0.80-0.84	0.87	0.69	4.00	3.00	3.37	.33	.47**	**.83**								
	3. LCf3: Learning support	2	0.70-0.86	0.76	0.62	4.50	3.00	3.66	.38	.28**	.74**	**.79**							
ONPEC				0.77	0.49														
	4. ONPDCf1: Employee involvement	3	0.53-0.90	0.80	0.58	5.00	2.67	3.65	.48	.54**	.47**	.20*	**.76**						
	5. ONPDCf2: Design simplification & modular design	3	0.59-0.77	0.71	0.51	5.00	3.33	4.10	.41	.07	.32**	.29**	.35**	**.71**					
OSIC				0.82	0.57														
	6. OSICf1: Supplier evaluation & selection	3	0.77-0.96	0.92	0.79	5.00	4.00	4.45	.43	.50**	.43**	.24**	.58**	.15*	**.89**				
	7. OSICf2: Supplier involvement	2	0.81-0.90	0.84	0.72	5.00	3.00	3.87	.56	.25**	-.02	-.05	-.05	-.01	.24**	**.85**			
BP				0.84	0.56														
	8. BPf1: Business competitiveness	4	0.75-0.96	0.92	0.75	4.00	3.00	3.24	.37	.68**	.44**	.08	.06	.32**	.45**	.47**	**.87**		
	9. BPf2: Manufacturing performance	4	0.52-0.77	0.73	0.52	4.00	3.00	3.26	.32	.25**	.63**	.19*	.50**	.51**	.68**	.04	.57**	**.72**	
	10. BPf3: Process efficiency	2	0.85-0.96	0.90	0.83	4.00	3.00	3.18	.35	.00	.19*	.34**	.20*	.21**	.06	-.35**	.05	.23**	**.91**

Square root of AVE is shown on diagonal in boldface within boxes.

** Correlation is significant at the 0.01 level (2-tailed);

* Correlation is significant at the 0.05 level (2-tailed).

[a] Control variable

[b] Item loadings and T-Stat. values are listed in Appendix A.

Table 3

Descriptive statistics, correlations and discriminant validity of the constructs.

Constructs	MAX	MIN	Mean	S.D.	1	2	3	4
Nature of business[a]	3	1	2.81	.53	.03	-.08	-.02	-.08
Employee number[a]	8	3	5.11	1.11	.01	.03	.09	.02
1. Learning Capability (LC)	3.89	2.89	3.37	.30	**.72**			
2. Operational NPD Capability (ONPDC)	4.67	3.17	3.88	.37	.37**	**.70**		
3. Operational Supplier Integration Capability (OSIC)	5.00	3.71	4.18	.36	.20**	.46**	**.75**	
4. Business performance (BP)	3.80	2.90	3.22	.28	.62**	.58**	.56**	**.75**

Square root of AVE is shown on diagonal in boldface within boxes.

** Correlation is significant at the 0.01 level (2-tailed)

[a] Control variable

Table 4

Background information of case firms.

Case firm	No. of employees	Area of expertise	Scope	Interview participants (duration)
A	~4,300	DMS* services, including 4C products (Computing, Communications, Consumer Electronics and Car Electronics)	International *(12 offices: 3 in Taiwan; 9 overseas)*	· 1 product director (80 mins) · 1 senior project manager (65 mins) · 2 senior R&D engineers (70 and 60 mins)
B	~3,500	EMS**, including electronic/optical components, computing , communications, consumer electronics and etc.	International *(4 offices: 1 in Taiwan; 3 overseas)*	· 1 senior project manager (80 mins) · 2 senior R&D engineers (40 and 60 mins)
C	~6,000	Brand name products including industrial computing, communication, server, consumer electronics, notebook, multimedia and etc.	International *(22 offices: 3 in Taiwan; 19 overseas)*	· 1 senior project manager (80 mins) · 2 senior product engineers (60 mins each)
D	~7,070	Brand name products including , communication, server, consumer electronics, desktop platform, notebook, multimedia and etc.	International *(17 offices: 4 in Taiwan; 13 overseas)*	· 1 senior quality manager (70 mins) · 2 senior R&D engineers (60 mins each)
E	~600	OEM# & ODM## services for network storage solution, disk to disk backup, network data storage and etc.	International *(6 offices: 1 in Taiwan; 5 overseas)*	· 1 senior product manager (70 mins) · 2 senior project managers (50 and 60mins)
F	~38,000	TFT-LCD*** modules and TV total solutions	International *(8 offices: 1 in Taiwan; 7 overseas)*	· 1 senior product manager (80 mins) · 2 senior R&D engineers (60 mins each)

*DMS: Design Manufacturing Service

**EMS: Electronics Manufacturing Service

OEM: Original Equipment Manufacturing

##ODM: Original Device Manufacturing

***TFT- LCD:Thin Film Transistor- Liquid Crystal Display

Table 5

Construct level regression analysis (unstandardized coefficients).

	Moderating effect of LC on ONPDC and OSIC with BP			Hierarchical moderated regression models				
Hypothesis			H1 and H2			H1		H2
Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
DV: Business performance (BP)								
Intercept	3.31	3.37	3.36	1.32	1.52	3.21	1.42	3.23
Control Variables								
Nature of business	-0.08	-0.07	-0.07					
Firm size	0.02	-0.03	-0.03					
IVs and MV								
Learning Capability (LC)		0.45**	0.40**	0.57**		0.37**		0.50**
Operational NPD Capability (ONPDC)		0.24**	0.21**		0.44**	0.27**		
Operational Supplier Integration Capability (OSIC)		0.36**	0.32**				0.43**	0.38**
Interaction terms								
ONPDC • LC			0.19**			0.32*		
OSIC •LC			0.17*					0.25*
R^2	0.01	0.62	0.67	0.38	0.33	0.53	0.32	0.33
Adjusted R^2	0.01	0.61	0.65	0.37	0.32	0.52	0.31	0.32
ΔR^2	---	0.61**	0.04**	0.37**	0.32**	0.20**	0.31**	0.01*
F change	0.54	87.42**	11.33**	99.56**	80.33**	61.32**	75.92**	43.41**

** Significance at $p < 0.01$ level;

* Significance at $p < 0.05$ level.

Table 6

Factor level hierarchical moderated regression models (ONPDCf•LCf→BPf) (unstandardized coefficients).

Hypothesis H1	Model 1	Model 2[a]	Model 3	Model 4	Model 5	Model 6
Variables						
DV: Business competitiveness (BPf1)						
Intercept	3.24	3.27	3.24	3.20		
DV: Manufacturing performance (BPf2)						
Intercept					3.26	3.25
IV and MV						
IT applications (LCf1)	0.57**	0.49**			0.19**	0.17**
Open communication (LCf2)			0.29**	0.36**		
Employee involvement (ONPDCf1)					0.22**	0.26**
Design simplification & modular design (ONPDCf2)			0.22**			
Interaction terms						
ONPDCf2 • LCf1		0.48**				
ONPDCf2 • LCf2				1.16**		
ONPDCf1 • LCf1						0.45**
R^2	0.11	0.55	0.20	0.48	0.26	0.31
Adjusted R^2	0.09	0.54	0.19	0.47	0.23	0.30
ΔR^2	0.09**	0.46**	0.19**	0.28**	0.23**	0.07**
F change	18.91**	24.46**	13.95**	89.22**	25.63**	18.37**

** Significance at $p < 0.01$ level;

* Significance at $p < 0.05$ level.

[a] Present in Fig. 3

Table 7

Factor level hierarchical moderated regression models (OSICf•LCf→BPf) (unstandardized coefficients).

Hypothesis H2	Model 1	Model 2[a]	Model 3	Model 4
Variables				
DV: Business competitiveness (BPf1)				
Intercept	3.24	3.36		
DV: Manufacturing performance (BPf2)				
Intercept			3.26	3.30
IV and MV				
IT applications (LCf1)	0.50**	0.53**	0.22**	0.12*
Supplier evaluation & selection (OSICf1)	0.28**	0.23**		
Supplier involvement (OSICf2)				
Interaction terms				
OSICf1 • LCf1		0.50**		
OSICf2 • LCf1				1.48**
R^2	0.25	0.65	0.09	0.45
Adjusted R^2	0.24	0.64	0.08	0.43
ΔR^2	0.24**	0.40**	0.08**	0.35**
F change	53.33**	31.18**	8.30**	109.80**

** Significance at $p < 0.01$ level;

* Significance at $p < 0.05$ level.

[a] Present in Fig. 4.

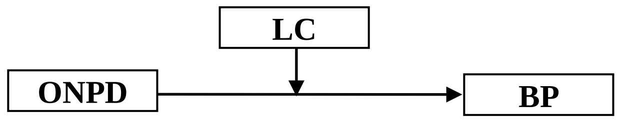
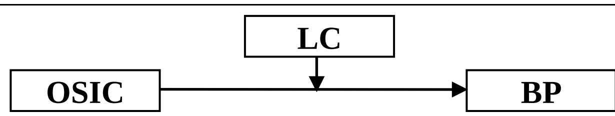
Table 8

Within-case analysis results.

Constructs/Factors	Rating of case firms					
	A	B	C	D	E	F
Learning Capability (LC)	High	Medium	High	High	High	Medium
· LCf1: IT applications	High	Medium	High	High	High	High
· LCf2: Open communication	High	Medium	High	High	High	Medium
· LCf3: Learning support	High	Low	High	Medium	Medium	Medium
Operational NPD Capability (ONPDC)	High	High	High	High	Medium	Medium
· ONPDCf1: Employee involvement	High	High	High	High	Medium	Medium
· ONPDCf2: Design simplification & modular design	High	High	High	High	Medium	Medium
Operational Supplier Integration Capability (OSIC)	High	High	High	High	Medium	Medium
· OSICf1: Supplier evaluation & selection	High	High	High	High	Medium	Medium
· OSICf2: Supplier involvement	High	High	High	High	Medium	Medium
Business Performance (BP)	High	High	High	High	Medium	Medium
· BPf1: Business competitiveness	High	High	High	High	High	High
· BPf2: Manufacturing performance	High	High	High	High	Medium	Medium
· BPf3: Process efficiency	High	Medium	High	High	Medium	Medium

Table 9

Predicted patterns representing regression models.

Hypotheses	Predicted patterns (PP)			
H1 (Interaction term: ONPDC·LC patterns)				
PP_ONPDC·LC*ha**	(High	·	High)	High
PP_ONPDC·LC*hb**	(Medium	·	High)	Medium
PP_ONPDC·LC*hc**	(Low	·	High)	Low
PP_ONPDC·LC*ma*	(High	·	Medium)	High
PP_ONPDC·LC*mb*	(Medium	·	Medium)	Medium
PP_ONPDC·LC*mc*	(Low	·	Medium)	Low
PP_ONPDC·LC*la*	(High	·	Low)	Medium
PP_ONPDC·LC*lb*	(Medium	·	Low)	Low
PP_ONPDC·LC*lc*	(Low	·	Low)	Low
H2 (Interaction term: OSIC· LC patterns)				
PP_OSIC·LC*ha*	(High	·	High)	High
PP_OSIC·LC*hb*	(Medium	·	High)	Medium
PP_OSIC·LC*hc*	(Low	·	High)	Low
PP_OSIC·LC*ma*	(High	·	Medium)	High
PP_OSIC·LC*mb*	(Medium	·	Medium)	Medium
PP_OSIC·LC*mc*	(Low	·	Medium)	Low
PP_OSIC·LC*la*	(High	·	Low)	Medium
PP_OSIC·LC*lb*	(Medium	·	Low)	Low
PP_OSIC·LC*lc*	(Low	·	Low)	Low

For examples:

*PP_ONPDC·LC*ha*: predicted pattern of interaction term ONPDC·LC, when LC level is high, scenario *a*, when ONPDC level is high.

*PP_ONPDC·LC*hb*: predicted pattern of interaction term ONPDC·LC, when LC level is high, scenario *b*, when ONPDC level is medium.

*PP_ONPDC·LC*hc*: predicted pattern of interaction term ONPDC·LC, when LC level is high, scenario *c*, when ONPDC level is low.

Table 10

Cross-case analysis results.

Case Firms	Construct rating				Hypotheses: match predicted patterns in Table 10 (supported by regression models)
	ONPDC	OSIC	LC	BP	
A	High	High	High	High	H1: PP_ONPDC·LC*ha* H2: PP_OSIC·LC*ha*
B	High	High	Medium	High	H1: PP_ONPDC·LC*ma* H2: PP_OSIC·LC*ma*
C	High	High	High	High	H1: PP_ONPDC·LC*ha* H2: PP_OSIC·LC*ha*
D	High	High	High	High	H1: PP_ONPDC·LC*ha* H2: PP_OSIC·LC*ha*
E	Medium	Medium	High	Medium	H1: PP_ONPDC·LC*hb* H2: PP_OSIC·LC*hb*
F	Medium	Medium	Medium	Medium	H1: PP_ONPDC·LC*mb* H2: PP_OSIC·LC*mb*

Figure Captions

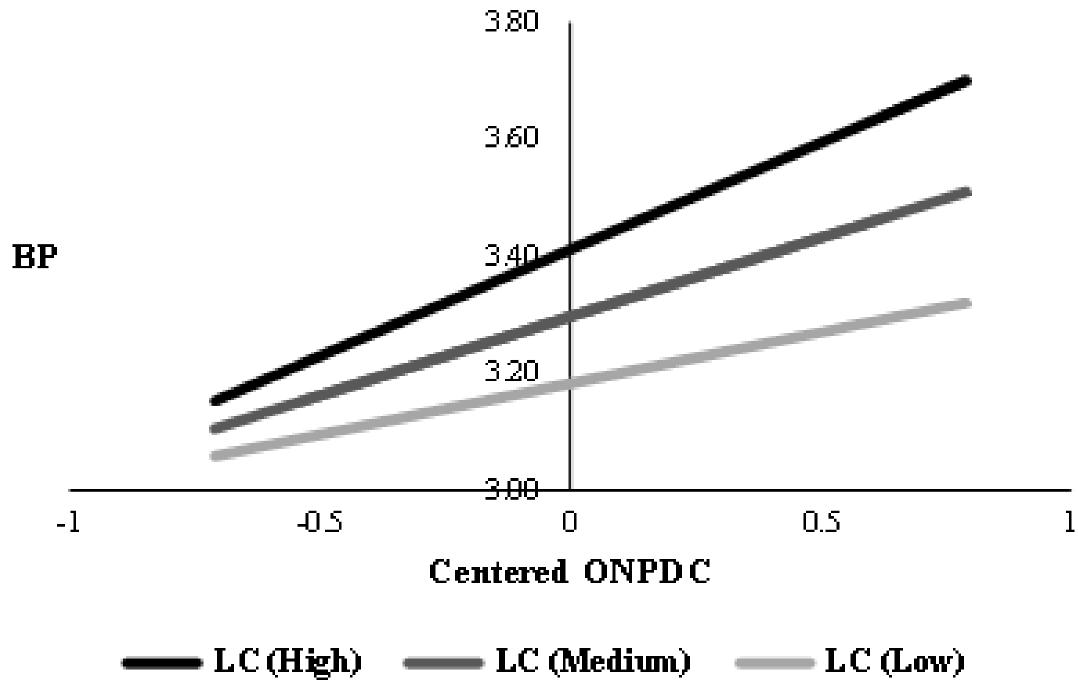


Fig. 1. Regression of BP on ONPDC at different levels of LC.

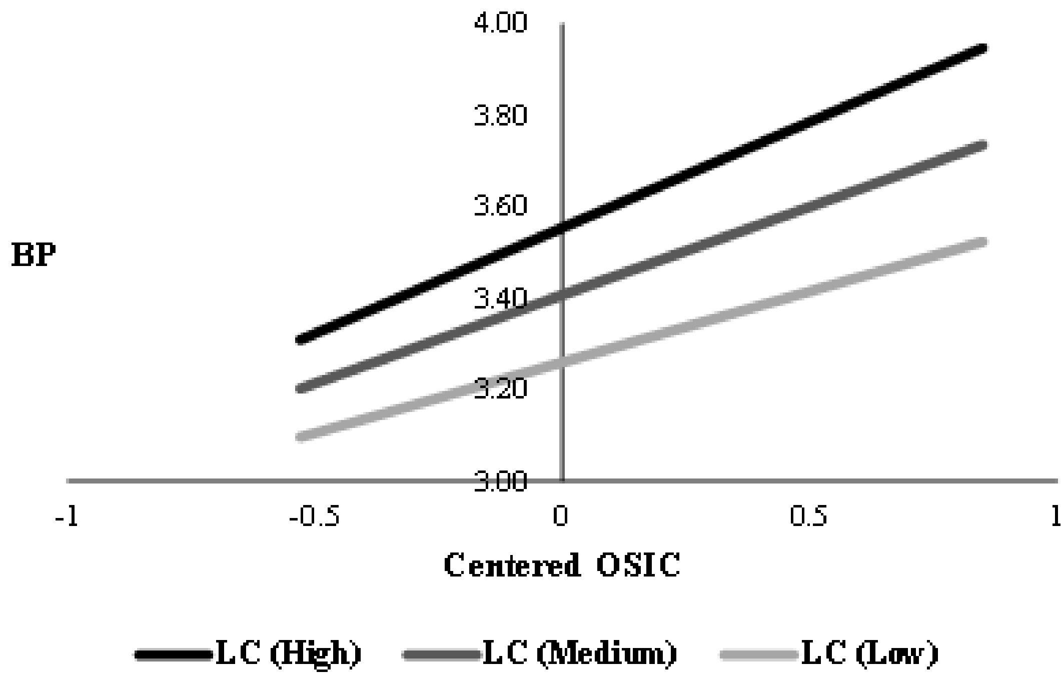


Fig. 2. Regression of BP on OSIC at different levels of LC.

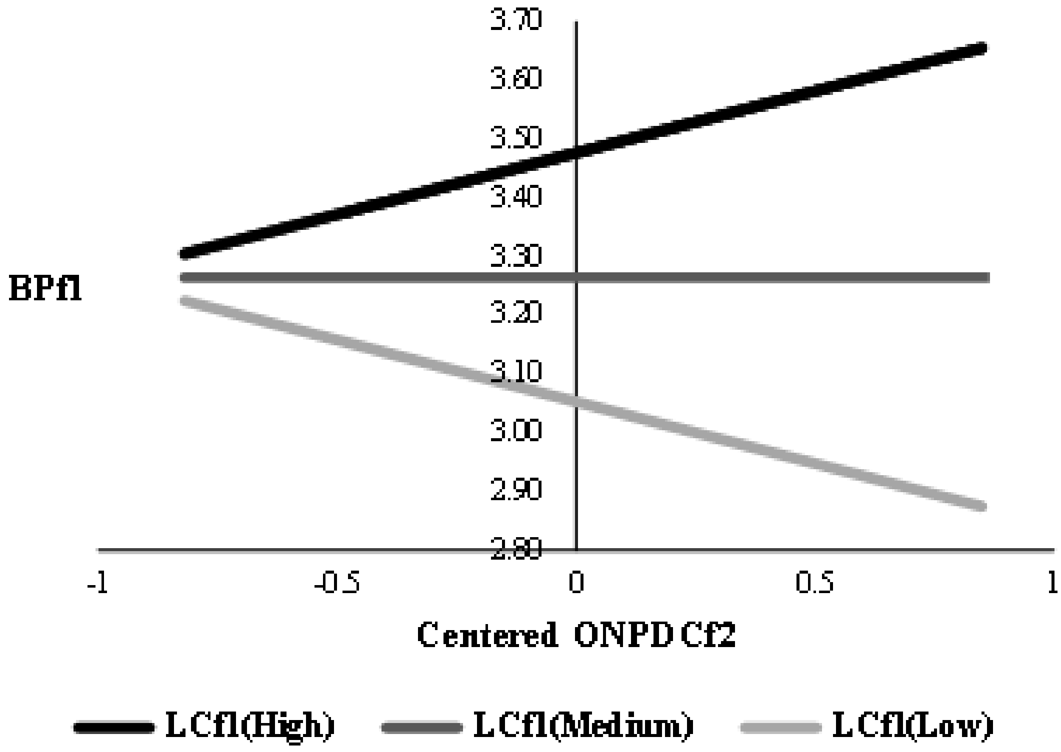


Fig. 3. Regression of BPf1 on ONPDCf2 at different levels of LCf1.

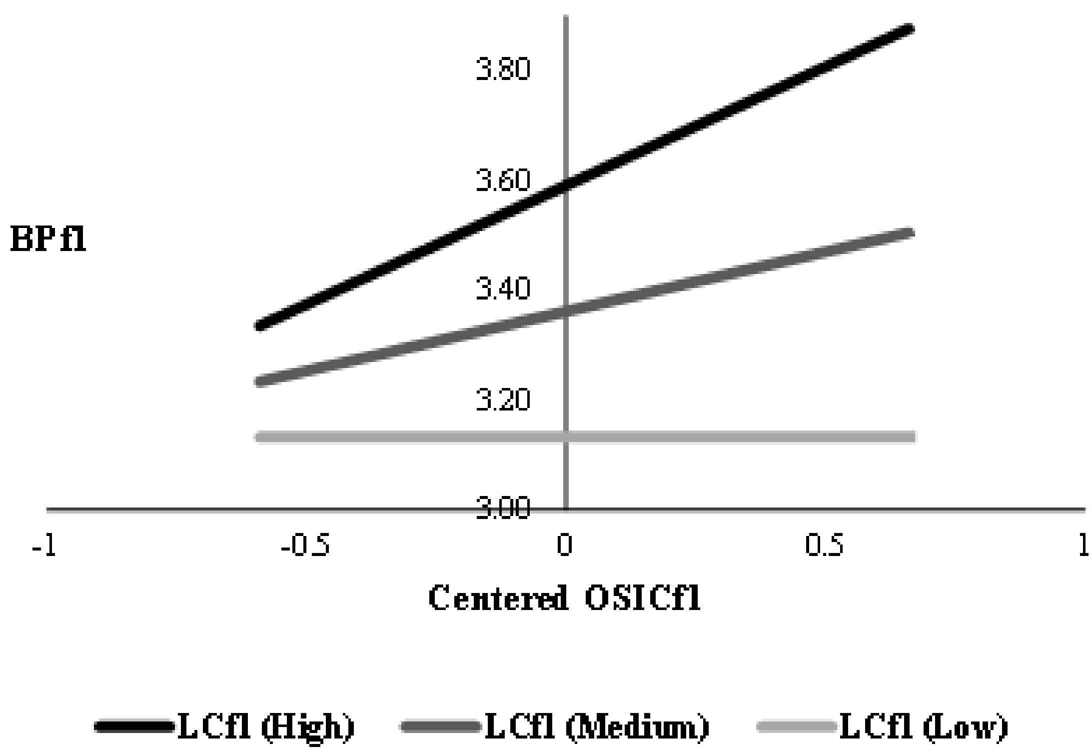


Fig. 4. Regression of BPf1 on OSICf1 at different levels of LCf1.

Appendix A Measurement items of the LC, ONPDC, OSIC and BP constructs

Statement in the questionnaire: The following statements are used to describe learning, new product development (NPD), and supplier integration practices as well as business performance (BP) of your firm during the last 12 months. Please rate (✓) your opinion for the following statements.

Scale: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree

Factors:	Statements:	PLS loadings based on original sample	PLS loadings based on 500 bootstrap samples	T-Stat	References
Learning capability (LC) construct					
LCf1 : IT applications	· Training new personnel on IT applications is a quick and easy job.	0.70	0.66	4.81	(Hsu, 2006; Renzl, 2008; Taylor, 2006)
	· New personnel can easily learn work processes by accessing the knowledge repositories.	0.86	0.85	17.56	
	· My firm provides user friendly IT infrastructure and abundant resources to support learning.	0.90	0.90	29.54	
LCf2: Open communication	· Continuous learning through open communication enhances employee abilities which improve work practices and processes.	0.84	0.84	37.09	(Carr and Pearson, 1999; Lichtenthaler and Lichtenthaler, 2009; Lubit, 2001; Modi and Mabert, 2007)
	· My firm/department updates the knowledge repository periodically based on open discussion.	0.86	0.85	36.51	
	· Employees are empowered to communicate potential useful knowledge obtained from internal/external sources with their managers.	0.80	0.80	27.81	
LCf3: Learning support	· My firm provides learning platforms and resources, such as tutor, training program, learning and sharing workshops, etc.	0.70	0.69	6.01	(Hsu, 2006; Lubit, 2001; Taylor, 2006)
	· Incentive or rewards is one of the factors that promotes learning and sharing in my firm and helps to establish learning environment.	0.86	0.86	12.36	
Operational NPD capability (ONPDC) construct					
ONPDCf1: Employee involvement	· Employees have received comprehensive training on product design and product quality improvement.	0.90	0.89	8.89	(Antonio et al., 2007; Mastui et al., 2007)
	· Employees are involved in the new product quality planning process.	0.81	0.80	5.46	
	· Product design and quality improvement plans include all functional areas (RD, quality, purchasing, marketing, finance, operations, etc.).	0.53	0.49	3.46	
ONPDCf2: Design simplification & modular design	· Modular product design is considered good practice when improving the efficiency of product design/development.	0.59	0.51	2.78	(Antonio et al., 2007; Fynes and Burca, 2005; Mastui et al., 2007)
	· Component standardization and/or reduced number of components have reduced product development time.	0.77	0.76	5.45	
	· Design simplification has reduced product development time.	0.65	0.54	3.63	
Operational supplier integration capability (OSIC) construct					
OSICf1: Supplier evaluation & selection	· Supplier capabilities complemented our business capabilities.	0.96	0.96	290.95	(Chin et al., 2006; Ndubisi et al., 2005; Tan et al., 1999)
	· In my firm, supplier evaluation and selection is an effective process to evaluate supplier performance (e.g. quality, cost, delivery).	0.93	0.93	47.89	
	· Selecting the "right" suppliers improves the firm's competitive advantage.	0.77	0.77	22.48	
OSICf2: Supplier involvement	· The supplier's involvement in projects led to improved decision making by the project team.	0.81	0.77	3.97	
	· The supplier's involvement in projects led to faster problem resolution by the project team.	0.90	0.89	7.46	

Appendix A (continued)

Factors:	Statements:	PLS loadings based on original sample	PLS loadings based on 500 bootstrap samples	T-Stat	References:
Business performance (BP) construct					
BPf1: Business competitiveness	· Sales growth rate has been increased.	0.96	0.96	171.19	(Antonio et al., 2007; Hsu, 2006; Kale and Arditi, 2003)
	· Profitability has been increased.	0.90	0.90	33.71	
	· Total quality cost* has reduced.	0.84	0.83	22.91	
	· Firm's competitive ability has been improved to gain or retain new business.	0.75	0.75	13.25	
BPf2: Manufacturing performance	· Customer satisfaction has been improved.	0.62	0.61	5.39	(Antonio et al., 2007; Beamon, 1998; Darroch, 2005; Hsu, 2006)
	· Customer retention rate has been increased.	0.52	0.51	3.31	
	· Product cycle time (from receipt of raw materials to shipment) has improved.	0.77	0.76	8.58	
	· Engineering changes rates has reduced.	0.61	0.60	5.62	
BPf3: Process efficiency	· Internal production rate has been increased.	0.85	0.71	2.93	(Devaraj et al., 2004; Maiga and Jacobs, 2007; Yeung, 2007)
	· Customer response time has been improved.	0.96	0.90	3.12	

* Sum of all costs associated with poor quality or product failure, including rework, scrap, and warranty costs and costs incurred in preventing or resolving quality problems.

Appendix B Measurement Scales for the Control Variables

Measures for 'nature of business':
Product design only = 1 Design and manufacturing mixed = 2 Product manufacturing only = 3

Measures for 'firm size' is indicated by number of employees:

Under 20 = 1	21-50 = 2	51-100 = 3	101-200 = 4
201-500 = 5	501-2000 = 6	2001-5000 = 7	Over 5001 = 8

Appendix C Sample Qualitative Assessment Rubric for OSICf*i* and Interaction Term

Factors	Rating criteria		
	High	**Medium**	**Low**
OSICf1: Supplier evaluation & selection	• Firm has very effective processes to evaluate supplier performance (e.g. quality, cost, capability, delivery). • Our supplier manager always seeks out and promotes new or innovative managerial practices with suppliers. • Our suppliers always take collaborative action according to our firm's instruction.	• Firm has moderately effective processes to evaluate supplier performance (e.g. quality, cost, capability, delivery). • Our supplier manager sometimes seeks out and promotes new or innovative managerial practices with suppliers. • Our suppliers sometimes take collaborative action according to our firm's instruction.	• Firm has unstructured processes to evaluate supplier performance (e.g. quality, cost, capability, delivery). • Our supplier manager rarely seeks out and promotes new or innovative managerial practices with suppliers. • Our suppliers rarely take collaborative action according to our firm's instruction.
OSICf1·LCf1: IT infrastructure and systems support	• IT infrastructure and systems are used intensively in the supplier evaluation and selection process. • E-platform/forum or database is always used to help conduct evaluation activities. • E-platform/forum or database is always used for training, education, lessons learned and past project experiences.	• IT infrastructure and systems are used moderately in the supplier evaluation and selection process. • E-platform/forum or database is sometimes used to help conduct evaluation activities. • E-platform/forum or database is sometimes used for training, education, lessons learned and past project experiences.	• IT infrastructure and systems are rarely or never used in the supplier evaluation and selection process. • E-platform/forum or database is rarely or never used to help conduct evaluation activities. • E-platform/forum or database is rarely or never used for training, education, lessons learned and past project experiences.
BPf1: Business competitiveness	• Total quality cost is markedly reduced. • Firm seems to be performing very well in terms of profitability (e.g. ROI) over the past years. • Product sales rate seems to grow very well over the past years. • Firm has a very competitive advantage (e.g. brand name, market share) when compared with its competitors.	• Total quality cost is fairly reduced. • Firm seems to be performing quite well in terms of profitability (e.g. ROI) over the past years. • Product sales rate seems to grow quite well over the past years. • Firm has a fairly competitive advantage (e.g. brand name, market share) when compared with its competitors.	• There is little or no reduction in total quality cost. • Firm seems not to be performing very well in terms of profitability (e.g. ROI) over the past years. • There is little or no growth in product sales rate over the past years. • Firm has little or no competitive advantage (e.g. brand name, market share) when compared with its competitors.