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Supply chain collaboration and innovation capability: the moderated mediating role of quality management

Shu-Hsien Liao[a*], Da-Chian Hu[b] and Yii-Shun Shih[a]

[a]*Department of Management Sciences, Tamkang University, No. 151, Yingjuan Rd., Danshuei Dist, New Taipei City, Taiwan, Republic of China;* [b]*Department of Food and Beverage Management, Jinwen University of Science and Technology, Xindian Dist., New Taipei City, 23154, Taiwan, Republic of China*

With the establishment of a collaboration supply chain mechanism enterprises can obtain greater opportunities to prosper within the current highly competitive business environment. These enterprises can then obtain sustainable competitive advantage and business excellence based on superior supply chain capabilities and improvement of operating costs, product quality, and innovation capabilities. The objects of this study are the upstream, midstream, and downstream suppliers of the supply chain for Taiwan's optoelectronics industry. A total of 454 effective questionnaires were recovered. The relationships of supply chain collaboration, supply chain capability, and innovative capability were tested through a structural equation model. Furthermore, quality management was used to explore the existence of the effect of moderated mediation in the research model. Finally, it was found that supply chain collaboration can directly and indirectly have a positive influence on innovation capability, and the effect of moderated mediation does exist in the research model.

Keyword: supply chain collaboration; supply chain capability; innovation capability; quality management; moderated mediation model

Introduction

Collaboration can be defined as working with others to complete tasks and to achieve shared goals. As such, it is a recursive process, in which two or more people or organisations work together: more than simply the intersection of common goals, as seen in co-operative ventures, they have a deep, collective, determination to achieve a common objective (Yung, Lee, & Lai, 2009). In particular, firms that work collaboratively can obtain greater resources, recognition, and rewards when facing competition for finite resources. Collaboration is one of the most frequently mentioned words in the study of supply chain management (SCM) (Lee, Cho, & Park, 2015). In the past several decades, there has been a need for firms to look outside their organisations for opportunities to collaborate with partners to ensure that the supply chain is efficient and responsive to dynamic market needs. Collaborative partner relationships can help firms to share information (Du, Lai, Cheung, & Cui, 2012), manage inventory levels (Yang, Chung, Wee, Zahara, & Peng, 2013), align supply chain (Ramanathan, 2013), manage risk (Quoc Le, Arch-int, Nguyen, & Arch-int, 2013), improve coordination (Wang & Du, 2010), create innovation capability (Wang & Wei, 2013), and enhance competitive advantage (Liao, Hu, & Ding, 2017).

For example, supply chain collaboration value innovation is a critical issue in SCM (Liao & Kuo, 2014). Supply chain collaboration provides access to new knowledge

*Corresponding author. Email: michael@mail.tku.edu.tw

since firms can learn and innovate from and with other organisations for better performance. For this, the benefits of supply chain collaboration innovation, and in particular of inter-firm collaboration, are evident. On the other hand, scholars have found that collaboration with external parties (e.g. through access to diverse sources of information) determines the degree of novelty of an innovation (Nieto & Santamaría, 2007). Vega-jurado, Gutiérrez-Gracia, Fernández-de-Lucio, and Manjarrés-Henríquez (2008) hence claim that a firm's capability to develop radically innovative business concepts that influence and even create business value and excellence requires not only a differential internal learning mode but also a different external perspective on collaboration and partnerships. We here consider supply chain information sharing as a critical external factor that may influence the effectiveness of deliberate learning mechanisms for innovation ability. Similarly, the benefits of information sharing with other parties may differ throughout different stages of the innovation process. In this regard, we can assume that the innovation capability by which supply chain members can exchange knowledge spontaneously through their normal, daily collaborative relationships could function as a platform to develop a deeper insight into the type of supply chain capability that innovation requires (Apostolos, Panagiotis, & Panagiotis, 2017). In other words, the amount of innovation capability provided by the supply chain quality improvement through collaborative relationships can be inferred to improve the effectiveness of supply chain capability.

With regard to quality management (QM), Prajogo and Sohal (2004) defined QM, quality learning and control, as (1) mechanistic with a focus on quality based on performance and (2) organic with a focus on employee development that supports innovation. Thus, we consider that specific elements of QM that support quality improvement are management support of quality, employee development, and employee involvement in quality decisions such as quality circles. Management support is required to develop an environment that supports employee development and empowerment in terms of developing innovation capability for a better competitive advantage. For example, O'Neill, Sohal, and Teng (2016) investigate whether a firm's stated quality orientation is useful in differentiating firm performance. They utilise longitudinal panel data gathered by the Australian Bureau of Statistics growth and performance survey over four years from financial years 1995–1998 and demonstrate that a firm's QM orientation does provide a statistically significant financial performance advantage through enterprise innovation.

With regard to industry, optoelectronics technology is an advanced technology based on the combination of optics, electronics, and motors. Its early stages focused on the defence and aerospace fields owing to the high technical threshold (Hung, Hung, & Lin, 2015). In recent decades, however, a variety of new products was introduced due to advances in optical technology, expanding into the fields of telecommunication, information, bio-chemistry, medicine, industry, energy, and livelihood. Therefore, most countries maintain an optimistic attitude towards the potential of the optoelectronics industry and have actively invested in its development (Wei, Yeun Chang, Zhang, Wu, & Tang, 2017). Considering the role of SCM in Taiwan's optoelectronics industry, in 2014, the output value of the optoelectronics industry in Taiwan was USD 67.4 billion, accounting to approximately 12% of the global output. However, Taiwan's firms have been primarily based on OEM production within the global optoelectronic industrial value chain, obtaining only limited profits. Thus, the production strategies opted by these enterprises were mostly for large-scale production in order to create economies of scale (Photonics Industry & Technology Development Association, 2015). At the same time, they adopted every action to reduce the production and manufacturing costs. They might opt for an SCM strategy so as to enhance the enterprises' innovative capability and introduce QM as a feasible strategy.

Hence, this study implements measurement tools to investigate these relationships in the case of Taiwan's optoelectronic industry.

Theoretical model development

Relationship between supply chain collaboration and supply chain capability

Koufteros, Vonderembse, and Jayaram (2005) used the concept of collaboration to explore the impact of supply chain integration on product innovation and product quality. The product's synchronised design, information sharing between the members, mutual trust between the members, and formation of a working team, joint-solutions for problems, executive involvement, manufacturing personnel involvement, early involvement in product design, and common education and training are all indicators that can be used for the measurement of collaboration design. Liao and Kuo (2014) confirmed the positive relationships among collaborative supply chain value innovation, supply chain capabilities, and firm performance by examining a case of the thin-film transistor liquid crystal display industry in Taiwan. Thus, the following hypothesis is proposed.

H1: Supply chain collaboration is positively related to supply chain capability.

Relationship between supply chain collaboration and innovation capability

As indicated by Lu and Yang (2004), R&D cooperation between enterprises helps to improve the development of new products. Fliess and Becker (2006) used the degree of internal development, exchange of know-how, the procurement of the parts or techniques, authorisation, contract development, coordination and other development, joint development, and joint development of contracts to measure the degree of collaboration between suppliers and their partners. Agarwal and Selen (2009) considered that service organisations increasingly create new service offerings that are the result of collaborative arrangements operating on a value network level. This leads to the notion of 'elevated service offerings', their definition of service innovation, implying new or enhanced service offerings that can only be eventuated as a result of partnering, and one that could not be delivered on individual organisational merits. Using empirical data from a large telecommunications company, we demonstrate through structural equation modelling that higher order dynamic capabilities in services are generated as a result of collaboration between stakeholders. They revealed empirical evidence for an ongoing process of continuous dynamic capability building in accordance with the changing dynamics of business. Managers of service organisations should recognise the potential embedded in these higher order skill sets, starting from collaboration, learning, and management of creative ideas for both strategic and operational benefits on innovation capability. They proposed that collaboration between upstream and downstream helped to improve the performance of enterprise innovation and competition in the process of establishing trust. Based on these previous findings, we conclude that supply chain collaboration is closely related to innovation capability. Thus, the following hypothesis is proposed.

H2: Supply chain collaboration is positively related to innovation capability.

Relationship between supply chain capability and innovation capability

In the current globally competitive environment, manufacturers of high-tech-intensive industries have increasingly adopted strategies designed based on collaboration between supply chain partners for new product development since this can shorten the life cycle of this development (Bidault, Despres, & Butler, 1998). In the process of interaction between the enterprises and the supply chain partners, both parties can better understand how to achieve effective decision-making, as well as obtain market information and a better understanding of the relevant operations that might drive the enterprises and organisations to produce knowledge and transform this knowledge into internal knowledge or capability. Montoya-Torres and Ortiz-Vargas (2014) found that the enhancement of supply chain capability was helpful to the firms' market and financial performance. Liao and Kuo (2014) showed that enterprises could increase the suppliers' technique and technology through improvements in supply chain capability. Schoenherr and Swink (2015) found that the central role of supply chain adaptability is in capturing the benefits of supplier technological intelligence for enhanced product innovation capability, new product launch success, and firm financial performance. In contrast, product innovation capability serves as the generative means by which customer and competitor intelligence is translated into more successful new product launches, which, in turn, produce superior firm financial performance. Their findings contributed to a better understanding of factors that can explain why certain product launches are more successful than others, and offer practical insights for appropriate investments in the development of related knowledge resources on supply chain capability and innovation capability. Based on these previous findings, we conclude that supply chain capability will affect innovation capability and propose the following hypothesis.

H3: Supply chain capability is positively related to innovation capability.

Relationships among supply chain collaboration, supply chain capability and innovation capability

McIvor and Humphreys (2004) showed that integrating the techniques and resources of key suppliers, thereby allowing the supply chain partners to be involved in the early stage of product design for new product development, was helpful for the technical capabilities of the enterprises to enhance product development and solve related issues. Therefore, the involvement of supply chain members enhanced the technological capabilities of the enterprises and responses to the customer's demands. Petersen, Handfield, and Ragatz (2005) also proposed a similar approach. These studies point out that the integration of suppliers during the process of product design and procedure design can help enterprises to reduce the time and cost of product development while supporting better quality and profit. Berghman, Matthyssens, and Vandenbempt (2012) indicated that strong supply chain partnership and supply chain capability are better for the stimulation of the increase of enterprise value innovation capability than the enterprises' internal mechanisms. Fawcett, Jonesb, and Fawcett (2012) found that by presenting a dynamic systems model that elaborates on the process of building trust to improve collaboration, innovation, and competitive performance. Based on the statements above, we conclude that supply chain collaboration will affect innovation capability through supply chain capability and propose the following hypothesis.

H4: The relationship between supply chain collaboration and innovation capability is mediated by supply chain capability.

Moderating effect of the industry level

Vokurka (1998) pointed out that a supply chain was an agreement between the buyer and the seller, including parties' promises, information sharing, and the bearing of possible risks and benefits. Stank, Daugherty, and Autry (1999) suggested that in response to the more recent developments in business practices, a change from the old organisational structure to cooperate the supply chain partners allowed a more complete realisation of customer demands or services than could be satisfied in the past service results. It was evident that the existence of the supply chain mechanism was significant for the survival of current enterprises. Owing to the existing characteristics of the upstream, midstream, and downstream elements of an industry, possible differences might exist in the correlation between supply chain collaboration and innovation capability when the industry is not at the same level. Golini and Kalchschmidt (2011) demonstrated that companies could limit this mediating effect by means of specific investments in the supply chain echelon and in their relationships with suppliers. This empirical analysis was based on data from the last edition of the International Manufacturing Strategy Survey. Their results show that companies performing global sourcing have invested in SCM and that this has been helpful in keeping their inventories under control. In addition, Zhou, Naim, and Disney (2017) investigated a three-echelon manufacturing and remanufacturing closed-loop supply chain (CLSC) constituting of a retailer, a manufacturer, and a supplier. Each echelon, apart from its usual operations in the forward supply chain, has its own reverse logistics operations. Their analysis suggested that a higher return yield contributes to reduced bullwhip and inventory variance at the echelon level, but for the CLSC as a whole, the level of bullwhip may decrease as well as increase as it propagates along the supply chain. The reason for such a behaviour is due to the interaction of the various model parameters and should be the subject of further analytical research. Thus, with regard to the moderating role of supply chain echelon, we propose the following hypothesis.

> *H5*: The moderation effect will be different between supply chain collaboration and innovation capability at different supply chain levels.

Moderated mediating effect of QM

Kannan, Tan, Handfield, and Ghosh (1999) used the concept of SCM to explore the impact of QM, customer relationship, and supplier management on supplier performance. It was found that if effective SCM could be established in an industry, its performance could be enhanced, while the competitive advantage could also be strengthened. This makes clear the key role of the advantages or disadvantages of SCM in the performance of the overall supply chain. Collaboration with key supply chain partners could be helpful for the development of new products, although the collaboration usually leads the companies to overlook the additional transaction costs (Srinivasan, Mukherjee, & Gaur, 2011) or product quality. Lotfi, Sahran, Mukhtar, and Zadeh (2013) considered that the design quality of the product could be affected by the supply chain scale. However, the impact of QM on the supply chain has received little discussion in studies related to supply chains. Based on previous studies, this research considers that the impact of supply chain collaboration on supply chain capability may differ according to the degree of QM degree, and thereby lead to different results. This means the supply chain may have a certain impact due to the impact of supply chain capability on innovation capability. Therefore, we propose the following hypothesis.

> *H6*: The indirect effect of supply chain collaboration on innovation capability through supply chain capability is stronger at higher levels of QM than at lower levels of QM.

Method

Research design

In the present study, we focus on exploring the relationships that supply chain collaboration, supply chain capability, innovation capability, and QM have on Taiwan's optoelectronic industry. According to the related literature and inferences, the theoretical model is illustrated in Figure 1.

Operational definitions and questionnaire design

This study follows Simatupang and Sridharan (2004) and defines the supply chain collaboration as the degree of information sharing, decision synchronisation, and incentive alignment between the supply chain partners. There are four items relating to each construct. Referring to other previous studies (Lynch, Keller, & Ozment, 2000), this study defines supply chain capability as the use of more efficient methods to reduce the operating costs and the continuous creation of additional value for customers, as well as the ability to improve customer satisfaction. There are five items relating to supply chain capability (Lynch et al., 2000). Innovation capability is defined as the performance of the enterprise going through various types of innovation and achieving an overall improvement of its innovation capability. This study employs three constructs used by Wang and Ahmed (2004) combining product, process, and marketing innovation aspects. There are 14 items relating to these constructs, 4 of which refer to product innovation, 5 of which refer to process innovation, and 5 of which refer to marketing innovation. This study also follows Motwani (2001) in defining QM as the guarantee of product quality by the organisation so as to improve customer satisfaction, and all methods are adopted from the product production and after-sale services. This study employs six constructs by Motwani (2001) combining system quality assurance, quality assurance, quality engineering, manufacture quality assurance, vender QM, and customer service aspects. There are 20 items relating to these constructs, 4 of which refer to the system quality assurance (Kristal, Huang, & Schroeder, 2010; Santos-Vijande & Álvarez-González, 2009), 3 of which refer to quality assurance (Santos-Vijande & Álvarez-González, 2009; Flynn, Schroeder, & Sakakibara, 1995), 4 of which refer to the quality engineering (Kristal et al., 2010; Flynn et al., 1995), and 3 of which refer to the manufacture's quality assurance (Kristal et al., 2010; Flynn et al., 1995), 3 of which refer to vender QM (Kristal et al.,

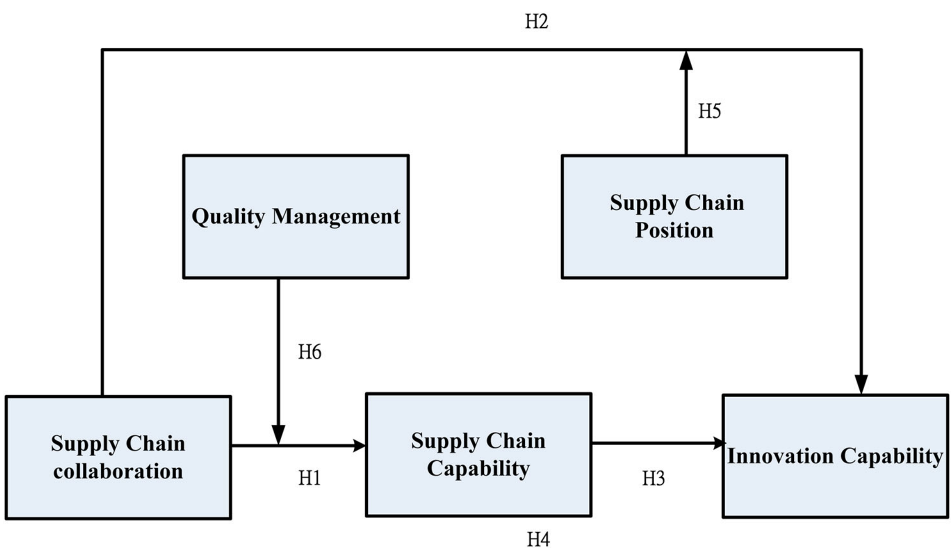

Figure 1. Theoretical model.

2010), and 3 of which refer to customer service (Santos-Vijande & Álvarez-González, 2009) (Appendix 1).

With regard to research samples, this research chose two suppliers each from the upstream, midstream, and downstream of the optoelectronics industry. Five questionnaires were given to each firm. A total of 25 effective questionnaires were recovered, achieving an effective recovery rate of 83.33%. A pre-test questionnaire was conducted to check where the questionnaire could be modified. After checking the reliability and validity of the received questionnaire, the results showed that the questionnaire did not need modification.

Analysis and results

Sample structure

This study took the optoelectronics industry as the sampling target, with a total of 59 suppliers, 23 from the upstream, 18 from the midstream, and 18 from the downstream. Fifteen questionnaires were given to each supplier to be completed by the firm's manager or superior managers at the level of an engineer or above. A total of 885 questionnaires were sent out. In response, 152 questionnaires were recovered from the upstream suppliers, 148 from midstream suppliers, and 154 from the downstream suppliers. A total of 454 questionnaires were recovered, for an effective recovery rate of 51.29%. Companies with an annual revenue between 100 and 1000 million comprised the largest group, accounting for 31.28%; companies established for more than 10 years accounted for 83.48%; and companies with more than 500 employees accounted for 63.66%. Companies with 325 male employees accounted for 71.59%, while companies with 129 female employees accounted for 28.41%. Respondents from R&D departments accounted for 27.09%, the largest group, followed by employees from the quality control department, accounting for 24.23%. Employees who worked as officers/engineers were the largest group according to position, accounting to 54.41%; while employees with one to three years of seniority were the largest group according to tenure, accounting for 33.92%.

Preliminary analyses

In the reliability analysis, Cronbach's are all between 0.78 and 0.90 in the validity analysis, the *t*-values of all questions are between 9.31 and 23.28 indicating excellent convergent validity. To assess discriminate validity, a series of difference tests were made on the factor correlations among all the constructs. This was done for one pair of variables at a time by constraining the estimated correlation parameter between them to 1.0 and then performing a chi-square difference test on the values obtained for the constrained and unconstrained models. The resulting significant difference in chi-square indicates that the two constructs are not perfectly correlated and that discriminate validity is achieved. All of the chi-square differences are between 17.86 and 720.94, which is good evidence for the dimensions' discriminate validity. Table 1 provides means, standard deviations, and intercorrelations for all constructs. All constructs were positively related to each other. The aforementioned correlated coefficients were related only to the relationships between some of the variables, although they provided a crucial basis for our further analyses (Effelsberg, Solg, & Gurt, 2014).

Measurement model

The confirmatory factor analysis (CFA) primarily explores the fit between a variable's factor and its measurement item in a questionnaire. The initial model for this study was

Table 1. Means, standard deviations and correlations.

Constructs	Mean	s.d.	CR/AVE	1	2	3	4	5	6	7	
1	Information sharing	5.86	0.84	0.87/0.63	1						
2	Decision synchronisation	5.47	1.02	0.98/0.94	0.60**	1					
3	Incentive alignment	5.35	1.00	0.91/0.77	0.48**	0.56**	1				
4	Supply chain capability	5.04	1.20	0.85/0.60	0.34**	0.37**	0.55**	1			
5	Product innovation	5.04	1.20	0.82/0.61	0.26**	0.37**	0.49**	0.59**	1		
6	Process innovation	5.01	1.03	0.77/0.53	0.24**	0.37**	0.49**	0.55**	0.79**	1	
7	Marketing innovation	5.31	1.11	0.81/0.60	0.24**	0.28**	0.44**	0.41**	0.67**	0.69**	1

Note: $N = 454$; $^{**}p < .01$.

modified because model indices did not fit well. In addition, this study deleted one item of supply chain capability and three items of innovation capability in order to achieve a good model fit. This study performed second CFA and we calculated the dimension score by averaging each item score. The overall model fit in the CFA model for all the constructs is as follows. The chi-square test for model fit was significant. Other fit indices should be taken into consideration as well. The values of the rest of the indices indicated that all the model fits achieve good model fit (χ^2= 444.69, $p < .001$; CFI = 96, GFI = 0.91, SRMR = 0.048, RMSEA = 0.078). These results provide evidence that a further examination of the structural model is justified.

Structural model

Table 1 displays the means, standard deviations, composite reliability (CR), average variance extract (AVE), and correlations for the constructs of research variables. Results indicate that the correlations between constructs are all significant and CR and AVE exceeded the recommended cut-off criteria (Fornell & Larcker, 1981; Hair, Black, Babin, Anderson, & Tatham, 2006). This study tests five hypotheses with the structural equation model. The result of the chi-square test for model fit was significant. Other fit indices should be taken into consideration as well. The values of the rest of the indices indicated that all the model fits achieve good model fit (χ^2= 156.94, $p < .001$; CFI =.96, GFI =.91, SRMR = 0.048, RMSEA = 0.078). These results provide evidence that a further examination of the structural model is justified. Figure 3 shows the results of the structural equation model of variables in this study. It indicates that the *T*-value of these paths including supply chain collaboration–supply chain capability, supply chain collaboration–innovation capability, and supply chain capability–innovation capability is significant; the parameter estimates are 0.63, 0.25, and 0.54.

Hypotheses testing

This study estimated the γ and β of the theoretical model by MLE to test whether each hypothetical path had achieved a significant level. Basically, an optimal sample size for MLE to estimate the structural model ranges from 100 to 150. Figure 2 shows the structural model with the standardised coefficients for the research sample. This study considered whether the supply chain collaboration relation would have a positive effect on supply chain capability (Hypothesis 1), supply chain collaboration relation would be positively associated with innovation capability (Hypothesis 2), and that supply chain capability would be positively associated with innovation capability (Hypothesis 3). Results indicate that there is a positive association between supply chain collaboration and supply chain capability (γ_{11}=0.63), thereby supporting Hypothesis 1. The relation of supply chain collaboration and innovation capability was significant and positive (γ_{21}=0.25), so Hypothesis 2 was supported. Because there was a significant positive relation between supply chain capability and innovation capability (β_{21}=0.54), Hypothesis 3 was supported. According to the LISREL8.8 output of direct and indirect effects (see Table 2), the results of Hypothesis 4 can be seen: the direct effect of supply chain collaboration to innovation capability is 0.25 and its indirect effect is 0.34 which indicates our research model is a partial mediation model and supply chain capability acts as a mediator role. Thus, Hypothesis 4 was supported.

The other issue this study considers is whether the supply chain position will affect the relationships between supply chain collaboration and innovation capability. If the path

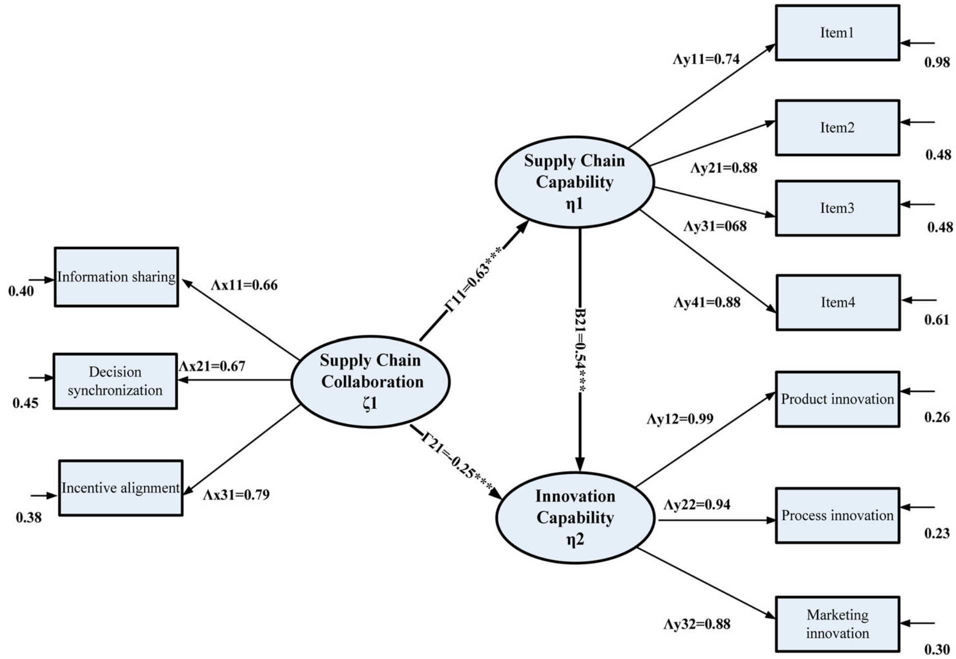

Figure 2. Path diagram of structural equation model.

coefficients were in fact significantly different for different supply chain positions (upstream, midstream, and downstream), the moderated effect would be proved. A multi-group baseline model with the parameters across three samples estimated was first established. A χ^2 difference test reveals a significant difference ($\Delta\chi^2 = 9.12$, $p<.05$) between the baseline and the constrained models for the supply chain position in both midstream and downstream positions (see Table 3). This suggests that the magnitude and significance of the relationships for midstream and downstream supply chain are not the same as for

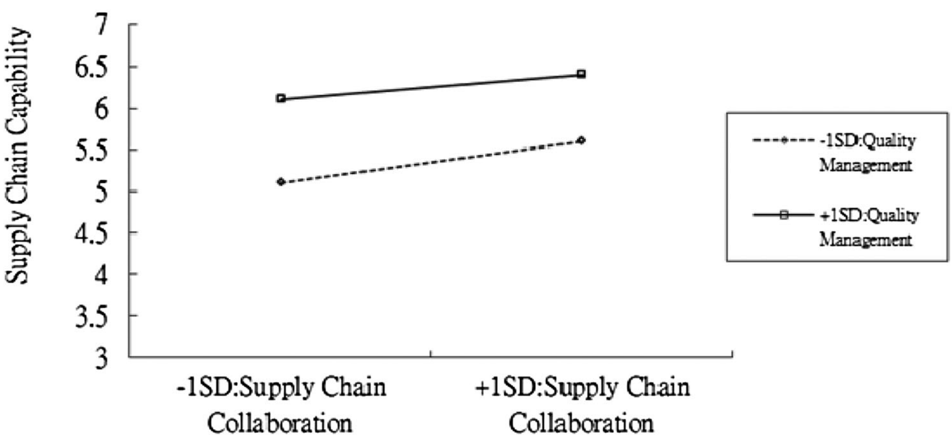

Figure 3. Moderated effect of management quality on the relationship between supply chain collaboration and supply chain capability.

Table 2. Total and indirect statistical effects.

	Mediator Supply chain capability			Outcome Innovation capability		
	E	*t*	*p*	*E*	*t*	*p*
Total effect				0.59	15.28	***
Direct effects						
Supply chain collaboration	0.63	9.25	***	0.25	11.3	***
Supply Chain Capability				0.54	7.38	***
Indirect effect				0.34	3.98	***

Note: $N = 454$; *E*: parameter estimate; ***$p<.001$.

upstream ones. The path coefficient of supply chain collaboration–innovation capability ($\gamma 11 = 0.07$) is different from and weaker than others in the upstream. These results show the supply chain position acts as a moderator in the relationships between supply chain collaboration and innovation capability. Thus, Hypothesis 5 was supported.

In order to test whether there is a moderated mediation effect in our research model (Hypothesis 5), this study first examined moderating effects of the QM on the relationship between supply chain collaboration and supply chain capability. We then further examined whether these effects moderated the indirect effect of the supply chain collaboration on innovation capability through supply chain capability. The results in Table 5 show that the cross-product term of supply chain capability × management quality in the outcome variable model (supply chain capability) was significant ($B = -0.12$, $p < .01$), Figure 3 revealed that the slope of the relationship between supply chain collaboration and supply chain capability was stronger for supply chain partners with a lower degree of management quality. We further validated the conditional indirect effect of the supply chain collaboration on innovation capability (through supply chain capability) at two values of management quality: one standard deviation above the mean (+1 *SD*) and one standard deviation below the mean (−1 *SD*). We generated bootstrap-based confidence intervals for the conditional indirect effects at three different moderator values. According to Table 4, the indirect effect through supply chain capability increased when conditional indirect effects were different from zero. These effects were based on the moderator values of M-1SD (average bootstrap estimate = .30, 95% CI [0.19, 0.44]). The conditional indirect effect became stronger to the level that the management quality as the moderator decreased. Furthermore, according to Table 5, the moderated mediation model was proven, which supports Hypothesis 6.

Managerial implications

This study presents several managerial implications. First, the results demonstrate that supply chain collaboration has a positive impact on supply chain capability. The analytical

Table 3. Path coefficients of the research models.

	Upstream	Midstream	Downstream
Supply chain collaboration→ Innovation capability	0.07	0.64***	0.31***

Note: Model fit indices: CFI = 0.96, GFI = 0.91, NNFI = 0.94; ***$p<.001$.

Table 4. Regression results for moderation and moderated mediation model.

	Mediator Supply chain capability			Outcome Innovation capability		
	E	*t*	*p*	*E*	*t*	*p*
Total effect				0.59	15.28	***
Direct effects						
Supply chain collaboration	0.63	9.25	***	0.25	11.3	***
Supply chain capability				0.54	7.38	***
Indirect effect				0.34	3.98	***

Note: $N = 454$; *E*: parameter estimate; ***p<.001.

results are consistent with previous research (Simatupang & Sridharan, 2005). It is apparent that a stronger supply chain collaboration in the optoelectronics industry leads to a greater supply chain capability. Through supply chain collaboration with incentive alignment, the supply chain partners can increase the competitiveness in the industry in the face of the greatly competitive market with synchronised product design, mutual sharing of information between the members, mutual trust between the members, the formation of working teams, and joint problem-solution. It is evidence that these companies have more opportunity for success with the integration of two or more independent enterprises for the joint planning and execution of operating activities rather than the operation of an independent company (Simatupang & Sridharan, 2002).

Second, based on the empirical results, supply chain collaboration clearly has a positive and direct impact on innovation capability. Accordingly, this research indicates that the firms in the optoelectronic industry should consider collaboration strategies with supply partners in order to continuously produce innovative and differentiated products, which will thereby improve the business performance and excellence (Akyuz, 2014). Therefore, this study suggests that innovation shall be considered as a basic value of an enterprise. Factors that impede the operation of the supply chain collaboration and strengthening of innovation capability should be found. Cooperation mechanisms should be created and information should be shared with supply chain partners in order to increase the overall performance of the supply chain (Santos, Miguel-Dávila, & Antolín, 2016).

Third, it is found that the results regarding supply chain capability have a positive impact on innovation capability, indicating that when suppliers of the optoelectronics industry have better SCM ability, the enterprises have a greater competitive advantage to increase their innovation capability. This study is consistent with the findings of Lu and Yang (2004) that collaboration and development of the enterprise teamwork are helpful to create new products. It is clear that comprehensive effects could be produced over the importance of suppliers with improved innovation capability. Thus, this study recommends that suppliers for the optoelectronics industry should strengthen their supply chain capability by internal review and external absorption so as to create chances for innovation growth.

Table 5. Index of moderated mediation.

Mediator	Index	SE	95% CI
Supply chain capability	−0.05	0.03	−0.12, −0.007

Fourth, this study shows supply chain collaboration has a positive impact on innovation capability through supply chain capability. Thus, this study recommends that if the optoelectronics industry wishes to increase the innovation capability of its enterprises, increasing the supply chain capability should be considered. When the enterprise's supply chain is strong enough and can collaborate with other supply chain partners, it will be able to effectively absorb the partner's knowledge and improve its innovation capability.

Fifth, in terms of the industrial structure of the upstream, midstream, and downstream within the optoelectronics industry, this study finds that the supply chain suppliers at a different position of the optoelectronics industry have different relationships with innovation capability and supply chain collaboration. The impact of the midstream supply chain collaboration in the optoelectronics industry has a greater impact on the innovation capability than the upstream and downstream suppliers. The downstream suppliers come next, while the upstream suppliers have an insignificant positive impact. This may be because the downstream segments of the optoelectronics industry are market and profit oriented. As innovation capability is of passive nature, the model of supply chain collaboration can acquire the knowledge or technology that it does not have via information sharing with the supply chain partners. After internalisation, the innovation capability and competition capability of the enterprise can then be enhanced. For the upstream suppliers, key parts and particular materials are limited by business secrets and exclusive patents. The joint product development with the supply chain partners may be a matter of concern due to the possibility of secret leakage; this can limit a firm's willingness to cooperate with its supply chain suppliers. Thus, the supply chain collaboration does not show significant benefits from increases in its own capability. Even so, with limited resources and abilities, product development based on collaboration has inevitably become a trend since it can reduce cost and improve overall performance.

Finally, this study uses supply chain capability and innovation capability as the moderator to explore the effect of moderated mediation within supply chain collaboration. The results show that for the relationship in which the supply chain collaboration increases the supply chain capability and strengthens the enterprise's innovation capability, QM actually plays a moderator role. This study proposes that one possible reason is the emphasis on collaboration between partners in the supply chain collaboration and business excellence. It is not easy to integrate different organisations, so the higher level of QM required may be a burden for this type of collaboration. This may weaken the relationships between the partners, impede the exchange and sharing of the information, and limit the increase of supply chain effectiveness. However, reinforcing the concept of quality in the goals of the partners must be an important aspect in the supply chain collaboration and best excellence strategy.

Conclusions, limitations, and future directions

Taiwan's government has considered the optoelectronics industry as a key industry for strategic development. To support its development, suppliers should develop effective supply chain collaboration, supply chain capability, and innovation capability. They should also understand QM operation and execution to increase the enterprises' innovation capability in the development of the optoelectronics industry with SCM advantages. Through supply chain collaboration, the supply chain partners may reduce their costs by aligning incentives, thereby enhancing industry-leading industrial conditions and strengthening competitive advantages by strengthening supply chain capability. Upstream suppliers can increase their product innovation capability, while midstream and downstream suppliers can strengthen innovation capability in the manufacturing processes. In addition, since quality is a vital concern, an enterprise will be better able to maintain good operating performance if it can include the concept of quality when enhancing its innovation capability. Despite its contributions, the results of this study should take into account the limitations of an empirical study.

First, since our research samples focus on Taiwan's photoelectric and optical sectors, the results of this study may not be suitable for this industry in other countries. In addition, to generalize its research findings to other industrial sectors must cautiously to generalise to other industrial sectors. Furthermore, there are three directions for future research in this area. First, follow-up suggestions may include a further exploration of whether the theoretical model in this study is applicable to the supply chain of a different industry, or through model competition, to understand the most suitable model for the supply chain of a different industry.

Second, the optoelectronics industry includes a wide range of fields, including optical storage or solar plants, which were not included in this study. They could be included in future research to develop a better understanding of the supply chain issue in the overall optoelectronics industry. Finally, since Taiwan's companies have increasingly close links to China's companies, it would be worth examining whether samples collected from Taiwan and from China yield differing results based on our research model.

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Appendices

Appendix 1. Items measuring supply chain collaboration

Information sharing

(1) In terms of information sharing, the mastering of the current external tendency and the prediction of future chances are important for the main suppliers of collaboration.
(2) In terms of information sharing, new product development and design modification (modification of functions) are important for the main suppliers of collaboration.
(3) In terms of information sharing, a company's projects and special exclusive knowledge are important for the main suppliers of collaboration.
(4) In terms of information sharing, new product features/utility solutions and services (service integration) are important for the main suppliers of collaboration.

Decision synchronisation

(1) Decision-making and joint planning by the suppliers in collaboration are fundamental for the mastering of future directions for development as well as the impact and business opportunities for the current business model.
(2) Decision-making and joint planning with the suppliers in collaboration can redefine the industry and the co-demands by the customers of other industries.
(3) Decision-making and joint planning with the suppliers in collaboration are fundamental for the development of new products and the demand of expanding into a new market.
(4) Decision-making and the co-joint planning with the suppliers in collaboration are fundamental for your company's planning and design of the specification of the new product.

Incentive alignment

(1) Your company may publicly discuss new goals with its collaborating suppliers in within meetings.
(2) In the communication of a new product/business with your collaborating suppliers, conflicts with the suppliers regarding revenue and market position could be prevented.
(3) Win-win cooperation is the vision shared by your company and its collaborating suppliers.
(4) Your company and its collaborating suppliers can agree to share the cost of new product/channel development.

Appendix 2. Items measuring supply chain capability

(1) Your company has the ability to simplify the procurement process with the suppliers, and eliminate unnecessary or repetitive operation procedures.
(2) Your company has the ability to provide products of stable quality according to a timetable.
(3) Your company has the ability to maintain good relationships with its customers.
(4) Your company has the ability to solve problems for its customers.
(5) Your company has the ability to standardize and unify the product and service operation procedures.

Appendix 3. Items measuring innovation capability

Product innovation

(1) Your company often develops products or services that can be accepted by the market.
(2) Your company has very high profit from the development of new products or services.
(3) When launching a new product or service, your company can always trigger its peers in the marketplace to learn from it.
(4) Compared to its peers, your company has stronger development ability in techniques related to product/service design.

Process innovation

(1) Your company usually tries different operation procedures in order to achieve its process innovation goals.
(2) Your company can often improve the process or the introduction of new technology or service process equipment.
(3) Your company can develop more efficient manufacturing procedures or operation procedures by itself.
(4) Your company can flexibly offer services or products required by its customers according to their needs.
(5) Your company uses efficient manufacturing processes or operating procedures that can trigger the learning between its peers.

Marketing innovation

(1) Your company latest product and service was developed from changes and adjustments made to earlier products and services.
(2) Your company can often use new products and services to cope with new competitors.
(3) Compared to its competitors, your company's latest product selling plan is very competitive.
(4) Your company's research development or resource investment on new product R&D cannot satisfy the demands of new product and service development.
(5) Your company's top management is willing to bear the risk to hold and explore future possible growing opportunities.

Appendix 4. Items measuring quality management

System quality assurance

(1) Your company is actively pursuing 'continuous improvement of product quality', rather than 'crisis management of poor quality'.
(2) Your company top management recognizes and provides incentives, depending on the situation, for its employees' contributions towards the refinement of product quality.
(3) Your company's production site management can establish and transmit the goals and visions of product quality refinement.
(4) Your company's top management supports your company in forming interdepartmental groups (for example, a Quality Control Circle) in order to solve product problems and improve quality.

Quality assurance

(1) Your company will adopt related recommendations provided by the employees of active participation in product quality improvement.
(2) Depending on the situation, your company will encourage employees to use team spirit to solve product quality problems.
(3) Your company can provide products or services demanded by the market.

Quality engineering

(1) Your company can provide reliable products and services.
(2) Your company provides highly reliable QC during the process of product delivery and service supply.
(3) Every employee of your company can immediately obtain information related quality performance.
(4) Your company can use a diagram to illustrate and confirm the production process control.

Manufacturing quality assurance

(1) Your company makes extensive use of statistical techniques to monitor the production process in order to reduce variation of production quality.
(2) Your company collects data on the inspection process for subsequent QC analysis.
(3) Your company uses the data of product defect rate as one of its manufacturing procedure improvement methods.

Vender quality management

(1) Your company will maintain good collaborative relationships with its suppliers.
(2) Your company will help its suppliers to increase their product/service quality.
(3) Your company will maintain close contact with its suppliers for product quality consideration and design modification.

Customer service

(1) Your company can understand the customers' present and future product needs (amount and features).
(2) Your company considers customer complaints as one of the methods to refine and enhance manufacturing procedure.
(3) Your company considers customers' quality satisfaction as its primary mission and principle.