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EMPIRICAL STUDY ON THE ROLE OF COLLABORATION IN NEW PRODUCT DEVELOPMENT IN MANUFACTURING COMPANIES

Abstract: *This paper provides new empirical evidence on the effects of internal collaboration (manufacturing involvement) and external collaboration (supplier and customer involvement) practices on NPD performance and success. Moreover, comparing the collaboration practices and their effects on NPD across 10 countries are provided. Data were collected from high-performance manufacturing (HPM) project with the sample of 265 manufacturing companies from 10 countries across the world. Descriptive, variance, correlation and regression analysis were conducted by using SPSS 22.0. Significant linkage between three collaboration practices and NPD performance & NPD success was found by statistical analysis. In addition, the results of this study reveal the significant differences in the implementation of collaboration practices across countries and the effects of those practices on NPD performance and success among countries. This study suggests that high performance and high success rate of NPD process could be achieved by external and internal collaboration in manufacturing companies.*

Keywords: *New product development, Collaboration, manufacturing involvement, Customer involvement, Supplier involvement, Performance*

1. Introduction

Nowadays, in a competitive and fast changing business environment, the role of product development has become increasingly important (Smith and Reinertsen, 1998). Under the pressures of bringing superior value to customers, organizations always seek the way to enhance product development performance regarding development time, cost and profitability (Neto et al., 2015). Therefore, the topic of how to achieve successful New Product Development (NPD) has been studied globally as an important business activity within the firm. Recent studies showed that the collaboration practices affect significantly to NPD process (Johnson & Filippini, 2010). This collaboration expands from internal practices (within company itself) to the external practices (within the supply chain). The collaboration in supply chain refers to the activity of knowledge sharing, co-development between functions within a firm (Liker et al., 1996) or between firms and other partners (Simatupang &

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Sridharan, 2002). Several works indicated that the integration of various functions in a firm can benefits the firm in new product development for example the cooperation of marketing and R&D (Olson et al., 2001), marketing and manufacturing (Swink & Song, 2007), manufacturing and design (Zhu et al., 2011). Besides, integrating with outside partners have been seen as important activity to achieve higher NPD performance (Lau, 2011; Petersen et al., 2003). Existing literature shows many works that focus on how internal collaboration or external collaboration practices affect NPD process. The number of literature that combine internal and external collaboration practices together to study their effect on NPD performance, however, still limited. This study aims at filling this gap by investigating the impact of internal collaboration practices in NPD (such as manufacturing involvement) and external collaboration practices in NPD (such as customer involvement and supplier involvement) on NPD performance as well as success in manufacturing firms all over the world.

In addition, most of existing researches related to NPD practices were conducted within a specific country and industry. Due to different contexts, the results among studies may be contrary. Because of globalization, business is becoming more international, understanding NPD process and collaboration practices across countries is essential. There are several researches that aimed to compare NPD practices between 2 different countries for example US and Japan (Johnson & Filippini, 2010), Japan and Italy (Matsui et al., 2007). This study analyzes the similarities and differences in the collaboration practices across countries and the impacts of the collaborations on NPD performance and NPD success in each country. We hypothesize that differences exists among countries in terms of collaboration practices and how those practices affect NPD performance as well as NPD success. Generally, this study is conducted to answer the following questions:

1) Do collaboration practices including manufacturing involvement, customer involvement and supplier involvement have positive linkage with NPD Performance and NPD Success?
2) What are similarities and differences in the perception of collaboration practices across countries?
3) What are the effects of collaboration practices including manufacturing involvement, customer involvement, and supplier involvement on NPD performance and NPD success in each country?

The remain of this paper present the literature review, analytical framework, data collection and analysis. Main findings, implications and conclusion are presented at the end of the paper.

2. Literature review

2.1. Concept of collaboration in supply chain management

According to Himmelman (1996), collaboration is defined as "exchanging information, altering activities, sharing resources and enhancing the capacity of another organization for mutual benefit and to achieve a common purpose". In operations management, collaboration means the company need to encourage the involvement of stakeholders, both inside and outside to achieve efficiency. When it comes to internal stakeholders, in case manufacturers and designers are separated, there can be constraints in product development because of different field of knowledge between designing and manufacturing process, so higher cost may occur. Therefore, for cost savings, companies developed a cross-functional team that allow effective communication between design developers and manufacturing engineers, marketing executives (Liker et al., 1996). That type of collaboration is called internal integration.

However, internal collaboration is not enough because focusing much on it makes the company being isolated.

In general, based on Simatupang & Sridharan (2002), supply chain collaboration involves 2 or more firms working together to plan and implement the supply chain operations. Nowadays, companies tend to collaborate with outside partners to have efficient supply chain then being responsive to market needs. As the business environment is going to be more cooperative, there is a need of open lines of communication in order to sustain the relationship between companies and stakeholders as well as ensure the mutual benefits of buyer and seller. Many previous researches studied about supply chain collaboration, however, they focused on individual element of supply chain integration for example customer involvement, supplier involvement (Frohlich and Westbrook, 2001; Zhao et al., 2008). However, in order to have more effective collaboration, the companies need to know the activities to collaborate with their partners, especially the practices and not just about information sharing. There are many interfaces that can connect customers and suppliers with the company's operations, such as supplier relationship management, customer relationship management, collaborative design, collaborative transportation, shared distribution (Barrat, 2004).

The impact of supply chain collaboration is still controversy that somewhat leads to procrastination of companies when implementing collaboration. There are many previous researches argued that collaboration can reduce cost, risk and improve capability of learning then lead to quick knowledge transfer and sharing (Park et al., 2004). Supply chain collaboration can also improve collaborative advantage and increase firm performance. By collaboration, firms achieve business synergy that is a win-win situation (Cao & Zhang, 2011). Moreover, involving partners of supply chain in operations management especially manufacturing firms can increase firm competitiveness, manufacturing practices in particular. It can be seen clearly from Japanese manufacturing practices especially automotive industry that they achieve all competitive features including high quality, low cost and fast delivery (Fearne et al., 2001). In addition, collaboration can promote decision making process in term of effectiveness as well as speed because collaboration allows corrective adjustments. However, collaboration could bring negative effect on the firm for example increasing cost due to coordination activities, slower decision-making and inflexibility because firms have to involve many parties in operations management (Das et al., 2006). Hence, many companies tried to apply supply chain collaboration but fail to meet participants' expectations, then become ineffective (Barratt and Oliveira, 2001). Collaboration is potential, but how to involve customers, suppliers as well as enable connection across functions in daily practices of the company is a major challenge and need more investigation.

2.2. New product development (NPD), NPD Performance and NPD Success

As regarded as the process that brings new product to market, NPD is the transformation of market opportunity into products available to sale through combination of activities that are implemented subsequently and in a logical way (Krishnan and Ulrich, 2001). NPD process would consist of four main phases: fuzzy front-end, product design, product implementation and fuzzy back-end. Fuzzy front-end is very first stage of NPD where ideas are generated and its success or failure help organization to decide whether to invest more on further steps or not (Reinertsen and Smith, 1998). The second stage is product design, which determines 70–80% of the final product quality and 70% of the product entire life-cycle cost (Zhou, 2009). Subsequently, design specification is

sent to manufacturing function to be executed. Lastly, the product is introduced to the market through fuzzy back-end or commercialization phase. For organizations especially manufacturing firms, the development of new and innovative products is crucial in a fast-changing environment (Matsui et al., 2007). Several previous studies have confirmed that NPD is vital for organizations to be able to survive in the market and it is key factor that drives organizations' success such as the study of Thomas (1995), he pointed out that NPD plays an important role in creating competitive advantage. Organizations can gain customers' need and market share by regular practices of NPD to satisfy 3 variables including cost, quality and delivery (time-to-market). Successful NPD can lead to sales growth and profitability improvement that contribute greatly to future growth of businesses (Matsui et al., 2007). Hence, many organizations now focus on developing effective NPD process.

As outlined in existing literature, NPD performance can be categorized into various types of performance including financial performance or time performance (Langerak & Hultink, 2005). Matsui et al. (2007) also pointed out that NPD performance can be illustrated by product quality in term of product capability to satisfy customer needs and product innovativeness compared to existing products. Anderson (2008) indicated that NPD performance depends on various factors for example NPD process; the organization of the NPD programs; NPD strategy; culture and climate for fostering innovation; and commitment of senior management to NPD.

New product success rate can be measured by the level of acceptance by customers, the profitability new product brings and its survival in the market (Ateke et al., 2015). Customer satisfaction and market share are two important measurements for NPD success because they indicate how new brand of the organization win the market over rivals. In case that below a certain level of market share, an organization might be deemed unviable (Ateke et al., 2015). Researches have shown that most new ideas fail when they are released in the market because structured process is lack (Owens & Davies, 2000), high degree of uncertainty and risk, high volume of information needed to transfer through many functions (Almeida & Miguel, 2007), as well as high associated cost. Recently, the elimination of barriers in communication in NPD has been more focused through using collaboration practices such as supplier involvement and inter-functional integration (Lau et al., 2011). According to Klein (1995), NPD process is becoming more collaborative as the requirement of interaction between various parties.

3. Analytical framework

The main target of this study is to investigate the linkages between NPD collaboration and NPD performance & NPD success as depicted in Figure 1.

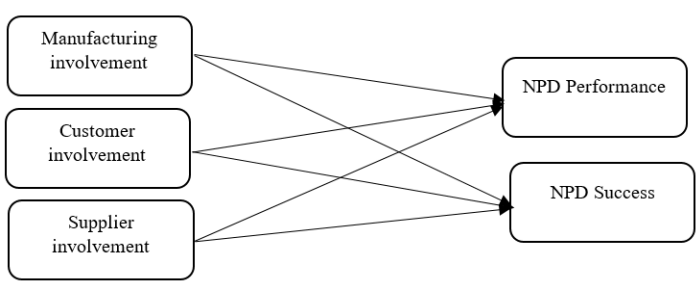

Figure 1. Analytical framework

2.2. Manufacturing involvement

Manufacturing involvement in designing process is considered internal collaboration in the firm, in which manufacturing function involves earlier in product design. In general, instead of separated functions, manufacturing and designing communicate with each other to reduce total time and even eliminate cost of defection. In production process, designing function includes product planning, concept design, design specification and revision. Besides, manufacturing is considered secondary function that receives blueprint from design team to manufacture the product. Recently, pressure of competitive market forces companies to develop new product faster with better quality and cheaper price. To do that, manufacturing companies must reduce cost and shorten the process of new product development. It can be achieved through concurrent engineering (Schönsleben, 2003). Concurrent engineering represents for manufacturing that involve in design team to improve product design and process. Since 1980, this approach was applied in many US as well as Japanese companies (Ettlie, 1995). This approach will benefit the production because there will be less mismatches between product characteristics and existing process capabilities. Moreover, manufacturing function can involve in designing function to suggest how the products are design for more economical to manufacture, for example: the products can be designed with fewer components, are easier to test and so on (Boothroyd & Dewhurst, 1990). Additionally, manufacturing can involve early in designing process to start manufacture while the product design is still developed. This approach is called product development cycle overlap, which requires manufacturing to learn knowledge of product design (Schönsleben, 2003).

Manufacturing involvement has been founded to have positive effects on operation of company. Many previous researches indicated that cross-functional development team can help firm to attain lower cost of production, high quality and shorter of time-to-market (Nafisi et al., 2016).

Manufacturing involvement also was found to reduce maintenance cost and fewer product recalls (Zhu et al., 2011). The effect of cross functional team on NPD success have been studied for decades by many scholars (Olson et al. 2001). Inter-functional collaboration in new product development refer the integration of various functions such as manufacturing, marketing, design in NPD team.

The involvement of other functions for example manufacturing creates better assessment of product concept design, and to clearly define module functions and interfaces. In addition, manufacturing involvement in design has significant effect on NPD time performance, since it assists to reduce development time and time to market. Danese & Filippini (2010) studied about impact of modularity on NPD indicated that inter-functional integration has significant mediating effect on NPD time performance. Turkulainen and Ketokivi (2012) found similar result that early involvement of manufacturing in product design eliminates redundant steps, preventing delays and accelerating ramp-up, as well as minimize duplicated efforts to complete product test and commercialization activities. Fleischer (1992) shows that communication between designers and downstream process facilitates the manufacturability of product and success in meeting customers' requirements.

The first two hypotheses can be presented as follow:

H1: Manufacturing involvement practice has positive linkage with NPD performance in manufacturing companies

H2: Manufacturing involvement practice has positive linkage with NPD success in manufacturing companies

2.3. Customer involvement

Customer involvement is regarded as the action of integrating customers in firm's value creation and delivery process (Iruka & Ateke, 2014). In more details, the collaboration and interaction between firms' members and customers are encouraged in many activities such as design, marketing, sales, customer service, so customers can be a part of business as well as product development process of the firm. Customer involvement takes several forms and somehow benefits organization in some extent. First of all, customers can help the organization by providing feedback and suggestions about company's products. Furthermore, in a more complicated form, customers can provide their ideas, financial as well as physical support to the development of technology in the firm. Specifically, when it comes to NPD, key customers participate in NPD process, incorporating with organization's members in problem solving and finalize products' design (Feng et al., 2010).

Existing literature has proved the importance of customers' involvement because it helps to maintain sustainable supply chain (Ariffin et al., 2012). For manufacturing firms, customers involve mainly in new product development process including product design, process engineering, and production operations (Ariffin et al., 2012). Firms will face less delays and mismatch between product's ideas and customer's needs if there are customers involved in product development.

Moreover, customer involvement is also advantageous in innovation process as the tool to decrease uncertainty and failure rates and increases revenue from new products (Rohrbeck et al., 2010). In addition, because the products can be more suitable for customer's needs, customer satisfaction is increased that lead to higher marketing as well as business performance (Ateke et al., 2015).

In NPD, customers may involve in two different forms which can be named as customer's involvement as information source and customer involvement as co-developers, according to Cui and Wu (2017). Because customer's involvement has strong impact on product innovativeness (Cui & Wu, 2017; Tsai, 2009), it leads to higher new product performance regarding financial performance (Cui & Wu, 2017). According to Singh et al. (2007), customer involvement can enhance NPD performance in terms of reducing NPD time and improving product quality. This result also is confirmed in other works for instance the studies of Rauniar et al. (2008) in automotive industry in US, Bonaccorsi and Lipparini (1994) in Italian manufacturers of food process and packaging machine. When it comes to NPD success, for a firm that has robust view of customer roles in NPD, it is more likely to achieve customer satisfaction and outperform competitors regarding time to market, acceptance as well as success rate. Gruner and Homburg (2000) studied about German machinery industry illustrate that when customers involve in NPD process except engineering stage, NPD success is enhanced. Chien and Chen (2010) found that customer involvement had significant effect on NPD success through the analysis of financial services firms in Taiwan. They pointed out that since customers are the people who buy the product, their effective contribution helps firms to reduce uncertainty.

The author proposes next 2 hypotheses based on existing literature review:

H3: There is positive linkage between customer involvement in firms' practices and NPD performance of manufacturing companies.

H4: There is positive linkage between customer involvement in firms' practices and NPD success of manufacturing companies.

2.4. Supplier involvement

Supplier involvement refers to action of integrating the suppliers' capabilities in the firm's supply chain and operations (Dowlatshahi, 1998). According to Echtelt et al. (2011), through supplier involvement, suppliers can provide their resources including capabilities, investments, information, knowledge, ideas in development of a part, process or service. Involving supplier in operations especially manufacturing companies can take advantage of suppliers' technological expertise in design and manufacturing (Dowlatshahi, 1998). Practically, suppliers mainly involve in several activities of the company for example just-in-time delivery, quality improvement, new product design and green purchasing (Krause, 1997). For instance, at early stage of new product development, supplier representatives who understand about manufacturing capabilities of the company can propose suggestions for product design in order to make it manufacturable.

Many studies indicate that supplier involvement brings various benefits for the company in term of productivity and performance. Firstly, collaboration with supplier helps firm to have good quality of materials from suppliers, so the firm can easier in achieving manufacturing goal (Narasimhan & Jayaram, 1998). Secondly, good supplier collaboration will benefit the firm in effective inventory management including optimal inventory levels and materials delivery. If the company and its supplier can share information, expectations and objectives, quality and delivery problems can be handled much easier (Kannan & Tan, 2005). Moreover, companies are trying to involve suppliers in designing process to improve decision making in product design as well as continuous improvement. Because supplier involvement facilitates the communication, knowledge sharing, the company can understand more deeply about customer requirements, culture, then fasten the decision-making process and also boost up manufacturing performance (Omar et al., 2006; Vonderembse & Tracey, 1999). For suppliers themselves, they also receive benefits regarding innovation, product quality and financial performance. In general, supplier collaboration or involvement have been found to be a necessary factor to enhance supply chain effectiveness and firm's competitiveness (Chang et al., 2006).

The effect of supplier involvement on NPD performance is strongly confirmed since 1990s by comparing between Japanese companies and US as well as Europe firms (Nishiguchi, 1994; Kamath and Liker, 1994). Lately, researchers are more focus on the time suppliers involve in new product development, leading to the concept of early supplier involvement. Hartley et al. (1997) indicated that supplier capabilities can help the firms to reduce risks of design-related delays in new product development projects. Added to this, Ragatz et al. (2002) found that supplier integration in new product development projects can benefits the firm in terms of cost, quality and cycle time. The cost of production is decreased because manufacturability is enhanced. As less reword and fewer scrap parts, quality of new product is more warranted, it might lead to higher product success. Firm can make use of suppliers' knowledge and capabilities to achieve higher quality, speed in design, market share, profit as well as reducing cost of production (Petersen et al., 2003).

The last two hypotheses can be stated as below.

H5: The involvement of suppliers in firms' practices has positive linkage with new product development performance of manufacturing companies.

H6: The involvement of suppliers in firms' practices has positive linkage with new product development success of manufacturing companies.

2.5. Data collection

This study utilizes data collected in framework of High-Performance Manufacturing (HPM) Project initiated in 1980s. The project was initiated by researchers at the University of Minnesota and Iowa State University with the aim at discovering the best practices for manufacturing companies to improve operational performance in a global competition.

The first round of the survey was initiated in 1989, gathering information from 46 US manufacturing plants. Round 2 was conducted in 1992 with the total number of plants is 146 when the project was expanded to other countries including Germany, Italy, Japan, and the UK. Until 2003, the project was expanded to Korea, Sweden, Finland, Austria, and Spain. The total number of manufacturing plants participated in the third round of the survey is 210 except Spanish plants. Round 4 survey was taken during 2013 – 2015 with data collected from 305 plants. Within each country, surveyed are plants with more than 100 employees belonging to one of three industrial fields – electrical and electronics, machinery, and transportation.

The researchers, based on business and trade journals and financial information, identified manufacturers as having either a "world-class manufacturer (WCM)" or a "non-WCM" reputation. Each manufacturer selected one typical plant for participating in the project. This selection criterion allowed for the construction of a sample with sufficient variance to examine variables of interest for the research agenda

The data used in this study was taken from HPM data round 4 and consist of 265 manufacturing companies in 10 countries including Brazil, German, Spain, Israel, Italy, Japan, China, Korea, Taiwan and Vietnam. The survey respondents are New Product Development team members. There were three measurement scales on NPD collaboration practices (manufacturing involvement in design, customer involvement, supplier involvement) and question items were evaluated in 5-point Likert scale (1: Strongly Disagree, 5: Strongly Agree). There were two measurement scales on NPD performance and NPD success and question items were evaluated in 5-point Likert scale (1: Significant worst, 5: Significant better) as presented in Appendix.

4. Data analysis

4.1. Measurement test

The first step of analytical process is the analysis of reliability and validity of five measurement scales. In this study, Cronbach's alpha coefficient is calculated to evaluate the reliability of each measurement scale country samples as well as pooled sample with acceptance value as 0.6.

Content validity: An extensive review of literature and empirical studies is undertaken about new product development and organization performance to ensure content validity.

Construct validity: Construct validity is conducted to ensure that all question items in a scale all measure the same construct. Within-scale factor analysis is tested with the three criteria: unidimensionality, a minimum eigenvalue of 1, and item factor loadings in excess of 0.40.

The results of measurement testing for the pooled sample and country-wise show that all scales reliable and valid as shown in Table 1 and Appendix.

Table 1. Measurement test

Measurement items	Descriptive		Cronbach's Alpha										
	Mean	SD	BRA	GER	ESP	ISR	ITA	JPN	CHN	KOR	TWN	VIE	Pooled sample
Customer involvement	3.952	0.684	0.811	0.799	0.886	0.815	0.848	0.796	0.790	0.872	0.612	0.673	0.819
Manufacturing involvement	3.665	0.684	0.739	0.817	0.786	0.796	0.841	0.843	0.832	0.789	0.865	0.721	0.818
Supplier involvement	3.729	0.773	0.727	0.877	0.827	0.647	0.949	0.892	0.842	0.856	0.878	0.602	0.840
NPD performance	3.604	0.481	0.708	0.778	0.768	0.868	0.886	0.778	0.845	0.901	0.878	0.913	0.859
NPD success	3.470	0.573	0.837	0.893	0.731	0.914	0.934	0.813	0.858	0.859	0.906	0.909	0.892

4.2. Hypothesis testing

The first step of data analysis process is to test the correlation between "Customer Involvement", "Manufacturing Involvement", "Supplier Involvement" and "New Product Development Performance" and "New Product Development Success" using pooled sample and the results are presented in Table 2 and 3.

It is found that 3 collaboration practices have positive correlation with all new product development performance items. In more details, the correlations are all significant, at 5% or 1% degree of significance, which indicates positive linkage between collaboration practices including manufacturing involvement, customer involvement, supplier involvement and NPD performance in manufacturing companies.

It is found that Customer Involvement, Manufacturing Involvement as well as Supplier Involvement have significantly positive correlations with all "new product development success" items with the significant level is 1%.

The results of correlation analysis suggest that all of 6 hypotheses should be supported for the pooled sample. These indicate that 3 collaboration practices consisting involvement of manufacturing, customer and supplier have significantly positive linkage with NPD performance and NPD success in manufacturing companies.

Table 2. Correlation between NPD collaboration practices and NPD Performance for pooled sample

Variable	NPDP01	NPDP02	NPDP03	NPDP04	NPDP05	NPDP06	NPDP07	NPDP08	NPDP10	NPDP11	NPDP13
Customer Involvement	0.218**	0.160*	0.230**	0.220**	0.211**	0.201**	0.185**	0.278**	0.273**	0.213**	0.313**
Manufacturing Involvement	0.353**	0.323**	0.232**	0.345**	0.318**	0.322**	0.426**	0.347**	0.372**	0.236**	0.222**
Supplier Involvement	0.301**	0.223**	0.143*	0.215**	0.281**	0.343**	0.272**	0.332**	0.224**	0.157*	0.179**

***. Correlation is significant at the 0.01 level (2-tailed).* **. Correlation is significant at the 0.05 level (2-tailed).*
NPDP: New product development performance.

Table 3. Correlation between NPD collaboration practices and NPD Success for pooled sample

Variable	NPDS01	NPDS02	NPDS03	NPDS04	NPDS05	NPDS06	NPDS07	NPDS08	NPDS10
Customer Involvement	0.364**	0.297**	0.294**	0.277**	0.183**	0.304**	0.177**	0.212**	0.329**
Manufacturing Involvement	0.349**	0.367**	0.330**	0.328**	0.348**	0.301**	0.383**	0.282**	0.357**
Supplier Involvement	0.254**	0.194**	0.251**	0.274**	0.286**	0.189**	0.270**	0.196**	0.277**

***. Correlation is significant at the 0.01 level (2-tailed). NPDS: New product development success.*

Table 4. NPD collaboration practices differences across countries (Country effect on collaboration practices)

Collaboration practices	BRA	GER	ESP	ISR	ITA	JPN	CHN	KOR	TWN	VIE	Pair-wise differences	F	Sig
Customer involvement	4.346	3.601	4.112	3.870	3.496	3.857	4.091	3.925	4.211	4.263	(BRA vs JPN), (GER vs ISR), (GER vs CHN), (ESP vs JPN), (ISR vs JPN), (JPN vs CHN).	5099.21	0.000
Manufacturing involvement	4.458	3.167	3.271	3.792	2.771	4.104	4.042	3.021	3.625	3.917	(BRA vs GER), (BRA vs ESP), (BRA vs KOR), (BRA vs TWN), (GER vs VIE), (ITA vs CHN), (JPN vs KOR).	1059.172	0.000
Supplier involvement	4.188	3.250	3.219	3.563	3.813	4.094	4.563	3.688	3.875	4.000	(ISR vs CHN).	513.074	0.000

Note: BRA: Brazil, GER: German, ESP: Spain, ISR: Israel, ITA: Italy, JPN: Japan, CHN: China, KOR: Korean, TWN: Taiwan, VIE: Vietnam.

One-way ANOVA was performed to test the country effect on collaboration practices among 10 countries. The purpose of this test is to discover the similarities as well as differences in collaboration practices between different countries. The last two columns in Table 4 indicate the F-statistics and the p-value of the test. We can observe that all of three NPD collaboration practices are significantly different between countries at 1% significant level. Besides, Turkey pair wise comparisons test assessing mean difference shows the difference in collaboration practices between each pair of countries. The smallest difference was found in supplier involvement as there is only a significant difference between Israel and China samples. We can also see that with the highest in manufacturing involvement, Brazil is differed with many other countries including German, Sweden, Korean and Taiwan in term of manufacturing involvement. The test results show that customer involvement in Japanese companies is significantly differed compared to other countries such as Spain and China. Interestingly, Vietnamese manufacturing companies and other 9 countries are quite similar or in other words, there is no significant difference was found between Vietnamese companies and others except Vietnam and German in manufacturing involvement. Brazil is the country that has highest in manufacturing involvement and customer involvement, the lowest of those collaboration practices are found in Italy. For supplier involvement, China has highest mean, while supplier involvement is lowest in Spain. The results also show the top practice that is the most focused practices in 10 countries: manufacturing involvement (in Brazil, Japan), customer involvement (in German, Spain, Israel, Korean, Taiwan, Vietnam), supplier involvement (in Italy,

China). In general, we can see the difference in collaboration practices among countries. Each country may evaluate the importance of each practice in different ways. These differences may be derived from the geographical, cultural and environment differences.

Subsequently, the binary correlation is performed to test the effects of 3 collaboration practices on NPD performance and NPD success measures. The result is indicated in the Table 5 and Table 6 below. For each country, if the collaboration practice is significantly correlated with NPD performance and success item (at 5% significance level), the country letter is put in the cell. There are 60 cells in total. For pooled sample, as tested above, all the collaboration practices are significantly positively correlated with all measures of NPD performance and NPD success. However, there are differences among countries. Out of 60, the number of pair of significant correlation in Japanese companies is 11, and for Vietnamese is 12. The lowest number of pair of significant correlation was found in Spain with only 1 significant correlation, while the highest number was found in Israel with 30 significantly positive correlations. For Japanese, we can see that the correlation mainly exists between manufacturing involvement and NPD performance and NPD success, while there are few significant correlations was found between customer involvement, supplier involvement and NPD indicators.

Table 5. Summary of Results of Correlation Analysis between NPD collaboration practices and NPD performance measures across countries

Variable	NPDP01	NPDP02	NPDP03	NPDP04	NPDP05	NPDP06	NPDP07	NPDP08	NPDP10	NPDP11	NPDP13
Customer involvement	P, BRA, ITA, VIE	P, BRA, JPN	P, ISR, VIE	P, BRA, TWN, VIE	P	P, VIE	P	P, CHN	P, TWN	P, BRA, GER, TWN	P, ITA, KOR, TWN
Manufacturing involvement	P, GER, ISR, ITA, JPN, KOR	P, GER, ITA, CHN, KOR, VIE	P, ISR, CHN	P, GER, ISR, CHN	P, ITA	P, ISR, ITA, JPN, KOR	P, GER, ISR, ITA, VIE	P, ITA, CHN, TWN	P, ESP, ITA, JPN, KOR	P, GER, ISR, JPN	P, ITA
Supplier involvement	P, BRA, ISR, ITA, KOR	P, ISR, KOR	P	P, ISR, TWN	P, ISR, JPN, KOR	P, ISR, JPN, KOR	P, GER, ISR, KOR	P, ISR, CHN, KOR	P, GER, KOR, VIE	P, GER	P, KOR

Note: P: Pooled sample; BRA: Brazil, GER: German, ESP: Spain, ISR: Israel, ITA: Italy, JPN: Japan, CHN: China, KOR: Korean, TWN: Taiwan, VIE: Vietnam.
NPDP: New Product Development Performance

Table 6. Summary of Results of Correlation Analysis between NPD collaboration practices and NPD success measures across countries

Variable	NPDS01	NPDS02	NPDS03	NPDS04	NPDS05	NPDS06	NPDS07	NPDS08	NPDS10
Customer Involvement	P, GER, ISR, ITA, TWN, VIE	P, GER, ISR, TWN	P, CHN	P, GER, ISR, TWN, VIE	P, GER	P, TWN, VIE	P, TWN	P, BRA, GER, TWN, VIE	P, GER, ISR, CHN, TWN
Manufacturing Involvement	P, GER, ITA	P, ISR, ITA, JPN, KOR	P, BRA, ISR, ITA, CHN	P, GER, ISR, ITA	P, ISR, ITA, JPN	P, ITA, JPN, CHN, VIE	P, ISR, ITA, JPN, CHN, TWN	P, GER, ISR, ITA, KOR	P, ITA, CHN
Supplier Involvement	P, ISR, KOR	P, KOR	P, ISR, CHN, KOR, VIE	P, GER, ISR, CHN	P, ISR, KOR, VIE	P, ISR, CHN, VIE	P, ISR, CHN	P, GER, ISR, KOR,	P, CHN, KOR

Note: P: Pooled sample; BRA: Brazil, GER: German, ESP: Spain, ISR: Israel, ITA: Italy, JPN: Japan, CHN: China, KOR: Korean, TWN: Taiwan, VIE: Vietnam. NPDS: New product development success.

To further investigate the relationship between collaboration practices and NPD performance, NPD success, regression analysis is implemented for pooled sample and 10 sub-samples for each country. Furthermore, Chow test was performed to test the differences in coefficients of relationship among countries (sub-samples). The F-statistic for Chow test is calculated based on Chow (1960) as follow:

$$\text{F-statistic} = \frac{(RSSR - \sum SSR_i)/k}{\sum SSR_i/(n - i*k)}$$

Where:

- RSSR is the sum of squared residuals from a linear regression of the pooled sample.
- SSR_i is the sum of squared residuals from a linear regression of sub-sample i.
- i is the number of subgroup (i = 10).
- k is number of independent variables (k = 3).
- n is number of total observations (n = 265).

Table 7 and 8 show the result of linear regression analysis for pooled sample and 10 sub-samples that represent for 10 countries.

Table 7. Regression Analysis on the relationship between NPD collaboration practices and NPD performance across countries

Independent variables		Dependent variable: NPD performance										
		Country										
		BRA	GER	ESP	ISR	ITA	JPN	CHN	KOR	TWN	VIE	Pooled sample
Standardized Coefficients (Sig.)	Customer involvement	0.370 (0.446)	0.366 (0.030)	-0.023 (0.940)	0.051 (0.783)	0.026 (0.882)	0.045 (0.825)	-0.412 (0.169)	-0.118 (0.555)	0.471 (0.039)	0.400 (0.329)	0.159 (0.017)
	Manufacturing involvement	0.054 (0.914)	0.229 (0.231)	0.070 (0.827)	0.413 (0.081)	0.643 (0.002)	0.512 (0.032)	0.449 (0.145)	0.140 (0.490)	0.194 (0.353)	0.148 (0.596)	0.333 (0.000)
	Supplier involvement	0.022 (0.973)	0.361 (0.062)	0.076 (0.801)	0.396 (0.080)	-0.041 (0.816)	0.093 (0.677)	0.411 (0.228)	0.667 (0.010)	-0.202 (0.355)	0.089 (0.819)	0.132 (0.073)
Adjusted R^2		-0.149	0.478	0.014	0.484	0.335	0.192	0.209	0.413	0.160	0.206	0.260
Degree of freedom (df)		11	24	16	19	28	20	27	24	29	18	225
F-statistic (regression)		0.523	8.326	0.060	6.948	5.710	2.586	3.383	6.640	2.843	2.560	27.312
Sig. (regression)		0.678	0.001	0.980	0.003	0.004	0.087	0.035	0.003	0.057	0.094	0.000
F-statistic (Chow test)		27.482										
P-value (Chow test)		0.000										

Note: P: Pooled sample; BRA: Brazil, GER: German, ESP: Spain, ISR: Israel, ITA: Italy, JPN: Japan, CHN: China, KOR: Korean, TWN: Taiwan, VIE: Vietnam. NPDP: New product development performance.

For pooled sample, adjusted R^2 equals to 0.260 and 0.240 indicating that collaborations practices can explain 26% and 24% the variation of NPD performance and NPD success respectively. Customer involvement and manufacturing involvement are found to have significantly positive impact on both NPD performance and NPD success. However, there is no significant impact of supplier involvement on NPD success. Supplier involvement only was found to influence positively to NPD

performance, but only at 10% significant level with p-value is 0.073. We can observe different regression results across countries. There is no significant effect was found in some countries such as Vietnam, Brazil and Spain. When it comes to Japan, only manufacturing involvement has significant impact on NPD performance and NPD success. In addition, we obtain the F-statistic for Chow test are 27.482 and 34.242, p-value is 0.000 that indicate there is significant difference on determinants of NPD performance as well as NPD success across the countries at 1% level of significance.

Table 8. Regression Analysis on the relationship between NPD collaboration practices and NPD success across countries

Independent variables		Dependent variable: NPD success										
		Country										
		BRA	GER	ESP	ISR	ITA	JPN	CHN	KOR	TWN	VIE	Pooled sample
Standardized Coefficients (Sig.)	Customer involvement	0.368 (0.439)	0.448 (0.021)	-0.226 (0.368)	0.201 (0.274)	0.033 (0.856)	0.087 (0.642)	-0.205 (0.462)	-0.207 (0.347)	0.568 (0.012)	0.331 (0.410)	0.197 (0.003)
	Manufacturing involvement	0.612 (0.232)	0.311 (0.154)	0.099 (0.704)	0.347 (0.103)	0.653 (0.002)	0.747 (0.002)	0.217 (0.446)	0.242 (0.279)	0.107 (0.598)	0.008 (0.978)	0.343 (0.000)
	Supplier involvement	-0.562 (0.383)	0.070 (0.737)	-0.118 (0.642)	0.390 (0.056)	-0.050 (0.783)	-0.255 (0.234)	0.582 (0.075)	0.541 (0.048)	-0.207 (0.330)	0.378 (0.329)	0.058 (0.431)
Adjusted R^2		-0.105	0.333	0.057	0.482	0.344	0.360	0.299	0.299	0.201	0.329	0.240
Degree of freedom (df)		11	23	20	20	26	19	27	24	29	15	224
F-statistic (regression)		0.651	4.823	0.340	7.203	5.552	4.557	4.845	4.413	3.439	3.451	24.637
Sig. (regression)		0.60	0.011	0.797	0.003	0.005	0.017	0.009	0.015	0.031	0.051	0.000
F-statistic (Chow test)		34.242										
P-value (Chow test)		0.000										

Note: P: Pooled sample; BRA: Brazil, GER: German, ESP: Spain, ISR: Israel, ITA: Italy, JPN: Japan, CHN: China, KOR: Korean, TWN: Taiwan, VIE: Vietnam. NPDS: New product development success

5. Discussion and implications

This study indicates the linkage between NPD collaboration practices including manufacturing involvement, customer involvement, supplier involvement and NPD performance as well as NPD success. Firstly, the manufacturing involvement was indicated to have significant impact on NPD performance and success. This result is in line with several researches in the past (Ettlie, 1995; Troy et al., 2008). The firms can promote manufacturing involvement by developing cross-functional team to enable knowledge sharing between functions in NPD for example design, manufacturing and marketing. Besides, another method is developing design-manufacturing chain. Manufacturing process can start prototyping and tooling from the detailed design stage, not waiting until the whole design phase is finished.

Secondly, customer involvement is correlated significantly to NPD performance and success of manufacturing firms in general. This result is with previous studies by Chien & Chen (2010); Lau, (2011), Cui and Wu (2017). Customers are the end users of product, so it is important to listen to them for better product quality and to meet

customers' expectations. According to Chien & Chen (2010), the organizations can easily collect customers' opinions through opinion boxes or interviews. Moreover, in case customers do not have professional knowledge, the company can still utilize customers' involvement to develop an effective marketing strategy. Therefore, customer involvement can reduce the time-to-market and enhance customer responsiveness. Furthermore, firms should involve customers as much as possible especially in design stage of any new product to reduce trial and errors. Depending the complexity of products that firms produce, the firm can integrate customers as co-developers to reduce the amount of experiment in NPD and lower the complexity of information sharing as well as involve customer in decision making process.

Thirdly, supplier involvement was found to have the positive impact on NPD performance, however no significant effect of supplier involvement on NPD success was found. The positive effect of supplier involvement on NPD performance was studied and found in many researches (Bonaccorsi and Lipparini, 1994; Song and Benedetto, 2008). Some researchers integrate supplier involvement and customer involvement in a study about NPD process as external collaboration practices (Chien & Chen, 2010; Lau, 2011; Sun et al., 2010). Collaborating with suppliers can benefit the manufacturing firms in terms of better delivery reliability and faster delivery speed, cost savings and higher product quality (Eisto et al., 2010). Hence, it is apparent that supplier involvement especially early supplier involvement in design can foster higher NPD performance. Nevertheless, since NPD success more depends in market share and time-to-market as well as customer satisfaction, insignificant impact of supplier involvement on NPD success is understandable. Supplier involvement can affect significantly to product quality; however, it can influence badly to whole projects of the supplier is critical (Primo & Amundson, 2002). Moreover, due to conflicts of ideas between supplier and company in product development, the process can be postponed and taking longer time-to-market. As more suppliers involve, the communication as well as required technology become more sophisticated, so the present of suppliers in product development does not always affect positively to product development success (McGinnis & Vallopra, 1999). For example, when it comes to Boeing case in developing "787 Dreamliner", the company believed that supplier involvement is crucial. However, due to intensive level of supplier involvement that include 50 partners, the development of "787 Dreamliner" incurred delays and technological issues (Yoo et al., 2015). Ittner and Larcker (1997) also showed that supplier involvement does not have substantial impact on new product development time, then influence negatively to NPD process. To develop effective supplier collaboration, the role of purchasing function should be highlighted in organizations to facilitate communication, information sharing, and development of a strategic infrastructure, since purchasing function interact mostly with suppliers.

The last important findings of this study are the diversification across countries. There are differences in collaboration practices among 10 countries. Moreover, significant difference between countries in the linkage of collaboration practices on specific NPD performance and NPD success indicators is detected. For example, the results illustrated that Brazil and Vietnam are two countries that implement collaboration in NPD process strongly. However, we could not find many significant correlations between those collaboration practices on NPD performance and success. Besides, the significant correlations were found in several countries with average scores of collaboration practices for example German, Japan or Israel. Hence, for national level, it revealed that high degree of collaboration practices

does not ensure the high performance and success in NPD. The implementation of collaboration practices may be ineffectively or unnecessary. For instance, research of Wu & Cu (2017) showed that close interactions with customers may not be necessary to improve product quality or performance. Previous studies have indicated that due to cultural differences, there might be differences in NPD collaboration practices (Song et al. 1998; Lee et al., 2000). In addition, the difference in the analysis result for each country can derive from geographical difference, different competitive environment. Moreover, key industry or product types in manufacturing companies for each country might be different, which leads to the difference in collaboration practices and their impact on NPD. The results provide an implication that each country should find its own path to high NPD performance and success depending on its specific context and competitive environment. Collaboration practices are necessary for NPD process, however for each country there are specific cultural propensities that support or prevent those collaboration practices (Johnson & Filippini, 2010). Those propensities should be determined for each country to take complete benefits of collaboration practices for NPD process.

6. Conclusions

This study significantly contributes to the literature by providing new empirical evidence on the impact of collaboration practices on NPD Performance and NPD Success. The result confirms the relationship between manufacturing involvement, customer involvement, supplier involvement and NPD performance. Manufacturing involvement and customer involvement have positive influence NPD success while significant impact of supplier involvement on NPD success could not be found. The result suggests manufacturing firms to take advantage of collaboration practices in NPD process because the information required in early product life cycle is always uncertain. Therefore, closer collaboration is needed for processing such information. In addition, the new findings of this study indicate that due to cultural and environmental differences, there are differences in the implementation of collaboration practices as well as their impact on NPD performance and success across the countries.

It is important to view this research in the context of its limitations. Methodologically, this study is conducted based on cross-sectional survey research data which were gathered from self-reported questionnaires, and individual bias in reporting may exist. Although we address the issue of common method bias through the use of multiple respondents, the study heavily relies on the use of perceptual data. The other issue is relative small sample size because of time and resources constrains. These restrict the scope of the studies and utilization of some data analysis techniques. For example, the small sample size not allows the authors to use path analysis technique to examine interrelations among specific NPD collaboration practices and operational performance with industry and country effects.

Future research should be conducted with larger size of data sample to overcome the limitations of this research as well as to provide more accurate results when comparing between countries. Researchers could explore both objective and subjective performance measures in their studies particularly when studying the link between the specific collaboration practices (e.g. manufacturing involvement) and the specific performance indicator (e.g. product quality) in specific industry (e.g. automobile). It is also suggested that the future researches can further explore the determinants of high performance and success of NPD process by adding new factors in the analytical framework. In addition, the relationship between collaboration practices and other manufacturing management practices could

be studied (e.g. innovation performance), which would provide significant and more interesting results.

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Appendix:

The data show the results of measurement test for each measurement scale including question items as well as factor loading for each item of the pooled sample. Besides, Eigenvalues and percentage of variance for the first factor of each scale taking on the pooled sample are provided. For example, the Eigenvalues and percentage of variance of scale "Manufacturing involvement" are 3.195 and 53.253% respectively.

Measurement of independent variables

Construct	Measured Items
Manufacturing involvement (3.195 and 53.253%)	1. Direct labor employees are involved to a great extent before introducing new products or making product changes (0.574). 2. Manufacturing engineers are involved to a great extent before the introduction of new products (0.705). 3. There is little involvement of manufacturing people in the early design or products, before they reach the plant *(this item is excluded).* 4. New product design teams have frequent interaction with the manufacturing function (0.747). 5. Manufacturing is involved at the early stages of new product development (0.681). 6. The manufacturing function is key in improving new product concepts (0.735). 7. Manufacturing is given challenging tasks in the development of new product concepts (0.619).
Customer involvement (2.606 and 65.158%)	1. We consult customers early in the design of new products (0.795). 2. We partner with customers for new product design (0.751). 3. Customers are frequently consulted about the design of new products (0.735). 4. Customers become involved in the design of new products only after the designs are completed *(this item is excluded).* 5. Customers are an integral part of new product design efforts (0.811).
Supplier involvement (2.708 and 67.705)	1. Suppliers are involved early in product design efforts (0.831). 2. We partner with suppliers for the design of new products (0.786). 3. Suppliers are frequently consulted during the design of new products (0.695). 4. Suppliers are an integral part of new product design efforts (0.766).

Measurement of dependent variables

Constructs	**Measured items** Please consider products that were recently launched. How do they compare with similar products that were manufactured and sold by your competitors? (1: Significant worst, 5: Significant better)
New Product Development Performance (NPDP) (4.863 and 44.211%)	NPDP01. Performance (functionality) (0.766) NPDP02. Features (0.752) NPDP03. Durability (life expectancy) (0.779) NPDP04. Reliability (time between failures) (0.822) NPDP05. Conformance quality (0.778) NPDP06. Aesthetic appeal of this product (0.535) NPDP07. Customers' perception of this product (0.703) NPDP08. Ease of servicing this product (0.558) NPDP09. Unit price *(this item is excluded)* NPDP10. Market share (0.599) NPDP11. Unit cost of manufacturing (0.765) NPDP12. Our ability to customize the product *(this item is excluded)* NPDP13. Our ability to rapidly deliver (0.757)
Constructs	**Measured items** Please consider products that were recently launched. How successful were they, in terms of reaching their goals? (1: Significant worst, 5: Significant better)
New Product Development Success (NPDS) (4.903 and 54.476%)	NPDS01. Customer satisfaction (0.797) NPDS02. Market share (0.735) NPDS03. Technical performance relative to specifications (0.802) NPDS04. Overall profitability (0.724) NPDS05. Return on investment (0.761) NPDS06. Time to market (0.533) NPDS07. Ease of manufacturing (0.723) NPDS08. Unit manufacturing cost (0.842) NPDS09. R&D budget *(this item is excluded)* NPDS10. Overall commercial success (0.631)