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Applications of Fuzzy Logic to Reconfigure Human Resource Management Practices for Promoting Product Innovation in Formal and Non-Formal R&D Firms

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Abstract: Human resource management (HRM) practices for promoting innovation tend to vary from one context to another. This leads us to investigate the configurations of internal HRM practices and supply chain collaborations that help firms to achieve high levels of product innovation or cause firms to achieve low levels of product innovation in formal R&D firms—firms which have actively engaged in systematic innovation, have established an R&D department, and/or have allocated budgets for R&D intention—and non-formal R&D firms. The data were collected during the period December 2016–February 2017 from manufacturing firms located in the Bangkok metropolitan area, Thailand. In total, 87 respondents were included for an empirical fuzzy-set qualitative comparative analysis. The results indicate that, first, formal and non-formal R&D firms achieve high levels of product innovation by adopting internal HRM practices or collaborating with customers/suppliers. They also can achieve high levels of product innovation if they adopt both simultaneously. Second, formal R&D firms achieve high levels of product innovation if they adopt R&D personnel development; otherwise, they need to collaborate with customers and suppliers to achieve high levels of product innovation. Finally, miss-adopting R&D personnel development causes formal and non-formal firms to achieve low levels of product innovation.

Keywords: internal HRM practices; supply chain collaboration; product innovation; technological capabilities; fuzzy-set qualitative comparative analysis

1. Introduction

Human resource management (HRM) practices for promoting innovation have been extensively studied across continents, countries, and industries. In Asia, researchers from, e.g., Thailand [1], India [2], Laos [3], Vietnam [4], Japan [5], Philippine [6], Singapore [7], Indonesia [8], and Malaysia [9], identified various HRM practices in the manufacturing industry. These qualitative studies proved that firms mainly realized how critical HRM practices are in creating values for promoting innovation and maintaining sustainable survival and growth in today's fast-changing business environment. In a quantitative study, researchers mainly adopt conventional methods, e.g., regression, correlations, mediators, and moderators, to study the effects or relationships of causal conditions on outcomes. For instance, Glaister Karacay, Demirbag et al. [10] defined HRM practices as, i.e., training and development, recruitment and selection, workforce planning, and performance appraisal; these are used as causal conditions to study their effects on firm performance. Ueki [11] studied the roles of top management,

internal HRM practices, and customer relationships in promoting innovation in non-formal R&D firms. Zhang, Edgar [12] studied relationships between HRM practices and innovation and identified whether innovation is a mechanism of HRM practices and firm performance. Results from these studies may not fully represent and explain what happens in the workplace, where different configurations of HRM practices are related differently for promoting innovation.

Researchers, moreover, mainly stated various best HRM practices, but are they really the best for all contexts? For example, Gill and Wong [13] highlighted five best practices of Japanese management styles, i.e., lifetime employment, seniority systems, house unions, consensual decision making, and quality control circles. These practices helped the Japanese firms to successfully manage, expand, and introduce their organizations into global markets. Among these practices, house unions, consensual decision making, and quality control circles are transferable to Singapore, but lifetime employment and seniority systems are problematic to adopt because of cultural differences [13]. This shows that HRM practices tend to vary from one context to another, where a single best practice of HRM practices in one context may cause problems in another context if the top management entirely adopts those practices without understanding the contexts of business operations and the cultures, norms, and values of local employees [14]. Jørgensen and Becker [15] stated that there is no one set of best HRM practices for promoting innovation, and that the best HRM practices should align with the context of the business operation (e.g., emerging or developed economies) and firm capabilities (e.g., formal R&D firms—firms which have actively engaged in systematic innovation, have established an R&D department, and/or have allocated budgets for R&D intention—or non-R&D firms). Hence, it is worth finding the best fit of HRM practices in accordance with our own context rather than adopting the best practices from an outside context [14].

The literature review mainly focuses on factors positively related to an outcome. For example, Ueki [11] proved that HRM practices help firms to achieve more process innovation, customer relationships help firms to promote product innovation, and the top management contributes to promote product innovation when she/he maintains relationships with engineers. However, are there any configurations that cause firms to have low levels of product innovation? This leads us to investigate the configurations of internal HRM practices and supply chain collaboration that help firms to achieve high levels of innovation and cause firms to have low levels of product innovation in formal and non-formal R&D firms using a fuzzy-set qualitative comparative analysis.

The remainder of this paper is organized as follows. Section 2 presents the literature review. Then, the methodology is presented in Section 3. Section 4 presents the results and discussions. Conclusions are recapped in Section 5. Then, the practical implications, limitations, and further studies are summarized in Section 6.

2. Literature Review

2.1. Internal HRM Practices

Internal HRM practices refer to a firm's activities in utilizing internal resources to create new knowledge for promoting innovation. Researchers mainly defined internal HRM practices based on their experiences and the context of studies, because understanding practices in accordance with the context is critical in making sense of what happened and providing appropriate solutions for problem solving [16]. For instance, Zhang, Edgar [12] defined HRM practices as (i) hiring and evaluating employees based on their abilities, skills, and performances; (ii) encouraging employees to engage in decision-making for problem-solving; (iii) offering special training to employees to enhance their knowledge; and (iv) providing flexible strategies and organizational environments to enable employees to develop critical thinking, specific abilities, and skills. These HRM practices were defined differently in the works of (1) Fey, Björkman [17], where HRM practices consisted of incentive systems, job security, employee training, career planning, decentralization, internal promotion, and complaint resolution systems; (2) Glaister, Karacay [10], where HRM practices consisted of training and development,

recruitment and selection, workforce planning, and performance appraisal; and (3) Shipton, Fay [18], where HRM practices consisted of recruitment and selection, induction, appraisal, and training.

From the Thai manufacturing context, Jeenanunta, Rittippant [1] highlighted three stages of HRM practices: (i) recruitment and selection, (ii) training and development, and (iii) retention and compensation. Across these three stages, Jeenanunta, Rittippant [1] highlighted various internal HRM practices, i.e., (i) Thai Oil adopts knowledge sharing, cross-functional operation, job rotation, innovation contest, and R&D personnel development; (ii) SCG Chemicals adopts learning by doing, knowledge transferred across firms, idea time sessions; (iii) PTT Global Green Chemicals engages employees with voluntary tasks, adopts cross-functional teams, conducts in-house training, and sends employees to train outside the company. These companies stated that these practices help to improve employee capabilities, make them ready for new task assignment, and change their mindset toward innovation. These practices help to foster learning and form a coherent system to facilitate the emergence of innovation at individual, team, and organizational levels [19]. Hence, this study focuses on in-house training [20], engineer rotation [21], R&D personnel development [22], and quality control circles [23] as the key causal conditions of internal HRM practices.

2.1.1. In-House Training

In-house training helps to improve and enhance employee capabilities for assigned jobs so that they are able to promote innovation. In-house training needs to be conducted regularly for the knowledge acquisition of newly recruited employees and knowledge upgrading of current employees so that they are ready for task assignment [8]. In-house training not only focusses on teaching new things to employees, but also on updating their knowledge to follow what is happening in today's fast-changing society [24]. In-house training helps employees to fully utilize their knowledge through, i.e., socialization, externalization, combination, and internalization, with co-workers at individual, team, or organizational levels [25]. The literature shows that investing in in-house training helps firms to enhance human capital firstly and organizational performance secondly [26,27]. Sobanke, Adegbite [20] highlighted the critical roles of in-house training for technical staff in accumulating firm technological capabilities. There are various practices which are defined for in-house training. For example, Norasingh and Southammavong [3] defined on-the-job training, attending training with customers, learning-by-doing, and field trips as in-house training. Similarly, Binh and Linh [4] defined in-house training as new staff recruitment and training through production management.

2.1.2. Engineer Rotation

Engineers are the key resources in helping an organization to deal with technical tasks which ordinary employees are mainly incapable of. Firms without engineers are mainly small firms with low technological capabilities where they do not have adequate resources to acquire engineers or do not require the roles of engineers in their organization because tasks mainly can be accomplished by ordinary employees. However, when there are transitions, e.g., upgrading from non-formal to formal R&D firms or expanding from 100% locally-owned to joint venture firms, firms mostly recruit engineers to deal with complex tasks. To make the roles of engineers even more critical, firms need to constantly check the capabilities of newly recruited and current engineers. This process helps firms to achieve the highest potential from every engineer. Hence, firms can enhance and improve engineer capabilities through engineer rotation practices. These practices help engineers to integrate their knowledge with the organizational knowledge as well as the supply chain partners' knowledge.

2.1.3. R&D Personnel Development

Small and medium-sized enterprises (SMEs) mainly do not classify the roles of engineers and R&D personnel, but large firms often do. R&D personnel are one of the main resources, like engineers, but R&D personnel tend to be allocated for promoting innovation [1]. Mohan [9] mentioned that firms provide technical and competency certification and soft skills training programs throughout the year

to enhance the competency skills of every employee; this is specifically designed for developing R&D personnel. Thus, the capabilities of R&D personnel can be enhanced through various practices, e.g., small group activities among R&D personnel, regular meetings to discuss problems/solutions among R&D personnel, and development of personnel in charge of R&D.

2.1.4. Quality Control Circles

Quality control circles are defined as small group activities where firms organize for space sharing—i.e., physical, virtual, and/or mental space—among their colleagues. The quality control circles intend to involve everyone in an organization to co-create new knowledge; Japanese firms believe that participation, cooperation, and collaboration through various circles can strengthen the vigor and efficiency of business operations [23]. The quality control circles benefit firms in various ways, e.g., in developing and producing low-cost products, improving the efficiency of existing equipment through modifications of plant layouts and work procedures, developing employee capabilities, and improving organizational performance [23]. Besides Japan, the quality control circles are also transferred through the investment of Japanese firms to other countries. Local firms, which are the suppliers of Japanese firms, are required to adopt the quality control circles. Toyota, for example, has adopted and exported quality control circles during the expansion of the production plants to Thailand. During its business operation, Toyota required local suppliers, e.g., Thai Summit, to adopt quality control circles. These practices are considered as one of the minimum criteria to be a Toyota supplier. Toyota believed that these practices improved local supplier capabilities to match the firm's standards. The quality control circles, moreover, are rooted in local suppliers through Toyota's supplier network; this network motivates suppliers to participate and share knowledge openly, prevents members from free-riding, and transfers tacit and explicit knowledge effectively and efficiently [28].

2.2. Supply Chain Collaboration

Besides internal HRM practices, firms also need to collaborate with external partners, e.g., customers, suppliers, competitors, consultants, R&D institutes, and universities. These help firms with knowledge acquisition, knowledge transfer, and knowledge co-creation, which are invisible and embedded outside an organization [29,30]. The importance of external partners can be found in various studies, e.g., (1) intra-firm and external networks positively affect firm innovation, and intra-firm networks are moderators between external networks and firm innovation [31]; (2) family member involvement reduces collaboration with vertical partners [32]; (3) firms with domestic collaboration tend to have more foreign partner collaboration, and this may provide firms opportunities to access novel knowledge which does not exist domestically [33]; (4) collaboration with firms in various countries helps firms to acquire varieties of scientific and technological knowledge to improve the firm absorptive capacity [29]; and (5) vertical collaboration helps firms to engage in innovation and optimize core competency, whereas horizontal collaboration helps firms to identify new opportunities in a new market [34].

Firms understand how critical collaboration is. It, for example, pools knowledge for problem-solving, creates places for knowledge sharing and integration, increases choices for decision making, and enhances learning within and across an organization [14]. However, not every firm is able to expose their organization to every external partner, because this requires firms to have adequate capabilities in human resources, financial capital, and experienced top management. Local firms in emerging economies, especially SMEs, have limited financial resources, low technological capabilities, insufficient infrastructure, and low managerial skills [35]. They may be incapable or not ready to collaborate with external partners, specifically with universities, research centers, consultants, and competitors. Most SMEs are only able to collaborate with suppliers to set up plants and improve current systems and with customers to improve products to match standard requirements. This is because customers and suppliers are upstream and downstream partners of the supply chain to help firms to achieve, align, and mobilize resources effectively and efficiently for promoting innovation [36]. Stock,

Greis [37] stated that supply chain collaboration is highly linked with the collaboration of firms and suppliers and customers across extensive enterprises. Therefore, this study considers only customer and supplier collaboration, because they mostly collaborate with firms in emerging economies.

Customer and supplier collaboration are mainly studied together. For example, (1) customers are important for product innovation, whereas suppliers are important for process innovation [38]; (2) supplier collaboration helps firms to achieve radical innovation, whereas customer collaboration helps firms to achieve incremental innovation [39]; (3) collaboration with one partner (e.g., customers) increases the likelihood of collaboration with a different partner (e.g., suppliers) [33]. Researchers also studied customer and supplier collaboration separately, e.g., (1) customer collaboration enables firms to refine R&D direction and enhance internal competencies by assisting in product design, technology, project management, and prototype assessment [40–42]; (2) relationships between supplier collaboration and innovation novelty might depend on the stages of supplier involvement (pre-design or commercialization stage) [43] and the innovation capabilities of suppliers [44]; (3) supplier collaboration has strong relationships with radical product innovation rather than incremental [45–47]. Researchers highlight how critical supply chain collaboration is, but studying supply chain collaboration without considering internal HRM practices may lead to biased conclusions. For example, if firms have adequate internal capabilities, they may not collaborate with suppliers; they just need to collaborate with customers to acquire new knowledge for promoting innovation. Therefore, studying supply chain collaboration in combination with internal HRM practices helps us to gain new insight and knowledge on sources for promoting innovation in formal and non-formal R&D firms.

2.3. Firm Technological Capabilities

Firms mainly adopt HRM practices based on their own capabilities. Large firms tend to have stronger capabilities and resources to invest in R&D [48,49], and they possess innovative advantages over smaller firms in terms of heterogeneous R&D activities [50]. Arnold, Bell [51] defined four phases of firm technological capabilities—technology use and operation, technology acquisition and assimilation, technology upgrading and reverse engineering, and R&D. These technological capabilities range from fundamental to the highest phases of technology use. In their studies, they define the states of firms for each phase of firm technological capabilities, but they do not identify HRM practices for promoting innovation. Then, Jeenanunta, Rittippant [1] identified types of HRM practices needed to upgrade the firm technological capabilities in each phase as (i) adopting training with joint venture partners and collaborating with suppliers for plant set up and operation; (ii) having specific recruitment and training packages; (iii) using cross-functional and project-based teams for promoting innovation; and (iv) acquiring R&D gurus, e.g., highly qualified personnel with Masters degrees and PhDs.

Tsuji, Ueki [52] and Intarakumnerd [53] grouped these capabilities as formal and non-formal R&D firms. Formal R&D firms are organizations with systematic and organized activities—e.g., they have engaged in systematic innovation, have established an R&D department, and/or have allocated budgets for R&D for promoting innovation and improving the firm's performance [54]. Whereas, non-formal R&D is a process of collecting, processing, and applying information for problem-solving [55]. Non-formal practices, e.g., designs, the utilization of advanced machinery, and training, are critical for promoting innovation, especially in low and medium technological industries [56]. Tsuji, Ueki [52] stated that formal R&D firms promote product innovation by cross-functional teams of production, engineering, marketing, and information technological usage, whereas non-formal R&D firms promote product innovation by HRM programs for employees, group awards for new suggestions, and ISO9000. Therefore, formal and non-formal R&D are the key indicators to define a firm's technological capabilities. From this study, they are defined as firms that have and have not allocated some portion of their budgets for an R&D purpose.

2.4. Product Innovation

Innovation is defined as changes in the products/services of a firm or the way that the firm produces them, changes in business models, improvements in management techniques, and modifications in the organizational structure [57]. Then, it is redefined as processes of exploration (i.e., inventing new knowledge) and exploitation (i.e., reusing existing knowledge in new contexts) [14], or processes of the development and implementation of existing ideas in a new context or new ideas on an existing context [58]. Innovation is highly context-oriented, so what works in one context may not be applicable in another context [59]. This highly depends on firm sizes, financial capitals, human resources, strategies and manufacturing capabilities, absorptive capacities, and collaboration levels with supply chain partners. Thus, innovative firms utilize existing knowledge/technologies or explore entirely new knowledge/technologies. They need to learn how to unlearn outdated practices and learn how to relearn new practices so that they can improve firm competency and drive innovation.

There are various types of innovation—e.g., product, process, packaging, organizational, position, and commercial [60]—but only product innovation is investigated in this study, because manufacturing firms mainly embed their innovative ideas in products. Product innovation is a process of improving existing products or introducing a completely new product [61,62]. Aminullah, Hermawati [8] mentioned that SMEs tend to achieve product innovation at a very basic phase—e.g., diverging from their own recipe and improving existing products through trial-and-error— whereas vertical-integrated firms and global-oriented large firms tend to achieve the highest phase of product innovation, e.g., the development of a new product based on existing technology and new technology through conducting their own R&D and/or collaborating with supply chain partners, universities, and/or research centers. Mangematin and Mandran [60] defined three features of product innovation—(i) improving existing products; (ii) producing products which are new to a firm, but had already existed in a market; and (iii) producing products which are new to a market. Similarly, Tsuji, Ueki [52], Tsuji, Idota [63], and Ogawa, Ueki [64] categorized product innovation as (i) redesigning packaging or significantly changing the appearance design, (ii) significantly improving existing products, (iii) producing new products based on existing technologies, and (iv) producing new products based on new technologies. This classification is adopted in this study because it shows various types of product innovation with different levels of difficulties.

From the literature review, this study investigates configurations of HRM practices, i.e., internal HRM practices and supply chain collaborations, that lead firms to achieve high levels and cause firms to achieve low levels for each type of product innovation in formal and non-formal R&D firms, as presented in Figure 1.

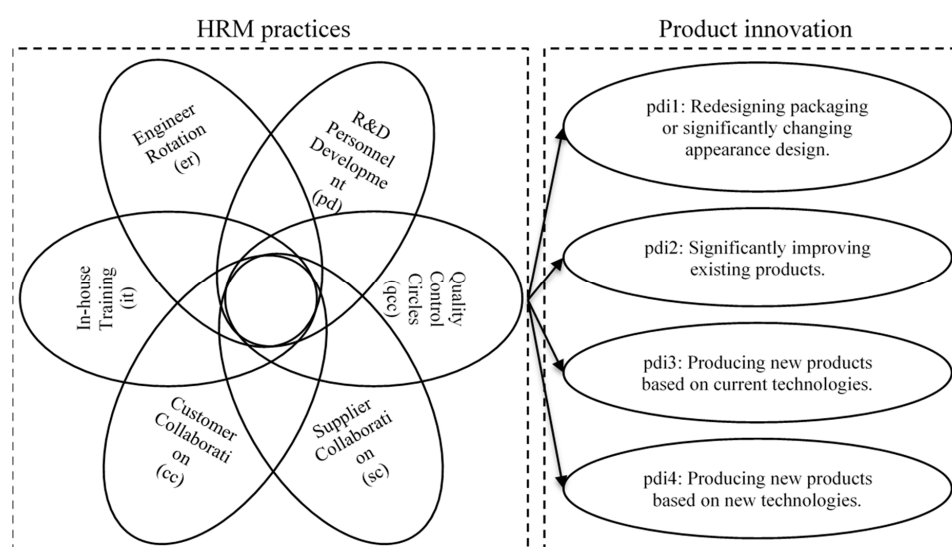


Figure 1. Theoretical model.

3. Methodology

3.1. Sample and Data Collection

This empirical study is motivated by in-depth case studies with Thai manufacturing firms [1]. An intensive literature review of HRM practices for promoting innovation was conducted. Combining knowledge from case studies and the literature review, a questionnaire—i.e., (1) profile of an establishment to provide the basic information of firms, (2) achievement for upgrading various types of product innovation, (3) internal HRM practices to promote product innovation, and (4) customer and supplier collaboration—was designed for data collection. The designed questionnaire was checked and commented on by three academic professors, who specialized in promoting innovation, for the questionnaire validation.

The questionnaire was distributed to firms located in the Bangkok metropolitan area, Thailand, because this area is a center of economics and the main gateway for national and international trade [65]. This area has major industrial zones and factories for data collection, and it is larger than other cities in Thailand. A list of 1200 firms was sampled on December 3rd, 2016, from firms that registered their business in the database of the Department of Industrial Works, Ministry of Industry, Thailand [66]. Each questionnaire was distributed to respondents who were expected to be key people in managerial positions, e.g., presidents, chief executive officers, directors, managers, heads of departments, or group leaders. The questionnaires were distributed and collected from December 2016 to February 2017. There were three means of data collection, i.e., email, post-office, and walk-in; the return rate for each mean was 2.08%, 2.67%, and 100%, respectively. In total, there were 209 respondents, which was equivalent to 17.42%.

3.2. Data Cleaning

There are three steps for data cleaning. First, the respondents who did not respond to the R&D expenditure were excluded from this analysis because we could not categorize whether they belonged to formal or non-formal R&D firms. Second, respondents were asked whether firms had product innovation in the last two years. If their response was “Yes”, they were required to answer each type of product innovation; otherwise, they went to the next questions without responding to each type of product innovation. Third, the data from respondents were analyzed by using a fuzzy-set qualitative comparative analysis (fs/QCA) [67]. This method cannot deal with missing data, so the respondents that had missing data on causal conditions and outcomes were removed. Across these three steps, 9, 68, and 45 respondents were removed from steps 1, 2, and 3, respectively. Therefore, only 87 respondents were included for further empirical fs/QCA.

3.3. fs/QCA

Fuzzy-set is defined as “a class of object with a continuum grades of membership, characterized by a membership function assigned to each object and ranged from zero to one” [68]. Ragin [69] introduced the fuzzy-set qualitative comparative analysis (fs/QCA) to deal with continuous and interval variables with causal complexity. Researchers who adopted fs/QCA believed that this technique combines the strengths of qualitative and quantitative approaches and that it is also the bridge between case-oriented and variables-oriented research. This is because fs/QCA does not analyze causal conditions in order to explain an outcome, but to explain how causal conditions combine in the complexity to generate an outcome [70]. There are various benefits of fs/QCA compared to conventional methods. For example, (1) fs/QCA can deal with equifinality, so it is able to explain various configurations that lead to a single outcome [71]; (2) fs/QCA can deal with asymmetry, so the presence or absence of a causal condition of an outcome requires different explanations [71]; and (3) fs/QCA can be analyzed with a small set of data [72]. Therefore, fs/QCA was adopted in this study.

3.3.1. Causal Conditions and Outcomes

The causal conditions, i.e., internal HRM practices and supply chain collaboration, were achieved from parts 3 and 4, respectively. They were measured by using the dichotomous scale, where 0 = “No” and 1 = “Yes”. The outcome, i.e., product innovation, was achieved from part 2 and measured using the three-point Likert scale [52,73], where 0 = “Not Tried Yet”, 1 = “Tried”, and 2 = “Achieved”. Details of the causal conditions and outcomes are presented in Table 1. The Cronbach’s alpha coefficient of the causal conditions in formal and non-formal R&D firms are presented in the last two columns to test the reliability of the constructed variables. The Cronbach’s alpha coefficient ranges from 0.727 to 0.920, so each constructed variable exceeded the threshold value of 0.7 [74]; they can be grouped together for a further empirical fs/QCA.

Table 1. Cronbach’s alpha of causal conditions and outcomes.

Internal HRM Practices, Supply Chain Collaboration, and Product Innovation		Formal (38)	Non-Formal (49)
In-house training (it)	<ul style="list-style-type: none"> • Employees develop training courses without help from outside. • Employees develop training materials without help from outside. • Employees serve as trainers/lecturers for training courses. • Firms have an in-house training facility/center. 	0.808	0.781
Engineer rotation (er)	<ul style="list-style-type: none"> • Firms have rotational programs for engineers to rotate around various roles in a department. • Firms have rotational programs for engineers to rotate around various departments. • Firms have career path programs for engineers to develop leaders of innovative activities. • Firms have external secondment programs to give opportunities for engineers to work in other firms. 	0.757	0.797
R&D personnel development (pd)	<ul style="list-style-type: none"> • Firms conduct small group activities among R&D personnel. • R&D personnel have regular meetings to discuss problems/solutions. • Firms develop personnel in charge of R&D. 	0.832	0.92
Quality control circles (qcc)	<ul style="list-style-type: none"> • Firms have systems to disseminate successful experiences of quality control circles across the firm. • Firms have systems to learn from successful experiences of quality control circles with customers/suppliers. 	0.782	0.777
Customer collaboration (cc)	<ul style="list-style-type: none"> • The main customer dispatches personnel to the firm. • Firms provide training to the main customer. • Firms receive training from the main customer. • Firms design a new product or service with the main customer. • Firms’ engineers obtain new technologies and knowledge through training/learning from customers. • Firms ask advice from/co-operate with foreign-owned (MNC/JV) customers. • Firms’ engineers communicate directly with the engineers of customers. 	0.759	0.807
Supplier collaboration (sc)	<ul style="list-style-type: none"> • The main supplier dispatches personnel to the firm. • Firms provide training to the main supplier. • Firms receive training from the main supplier. • Firms design a new product or service with the main supplier. • Firms’ engineers obtain new technologies and knowledge through training/learning from suppliers. • Firms ask advice from/co-operate with foreign-owned (MNC/JV) suppliers. • Firms’ engineers communicate directly with the engineers of suppliers. 	0.727	0.783
Product innovation	<ul style="list-style-type: none"> • Redesigning packaging or significantly changing appearance design. (pdi1) • Significantly improving current products. (pdi2) • Producing new products based on existing technologies. (pdi3) • Producing new products based on new technologies. (pdi4) 		

3.3.2. Variables Calibrations

The causal conditions and outcomes need to be normalized into fuzzy variables, which range between 0 and 1 [69]. There are three steps to normalize internal HRM practices, supply chain collaboration, and product innovation. First, every variable must be ranged from 0 to 1, so no normalization is needed for every sub-variable of the internal HRM practices and supply chain collaboration. However, the values of every type of product innovation need to be normalized between 0 and 1. If respondents answer 0, 1, or 2, the values need to be normalized as 0, 0.5, or 1, respectively. Second, there are sub-variables in in-house training, engineer rotation, R&D personnel development, quality control circles, customer collaboration, and supplier collaboration. Thus, an average value for each variable needs to be calculated. The first and second steps are necessary to make the scale of causal conditions and outcome range between 0 and 1. Then, data from steps 1 and 2 are transformed into set membership scores ranging between 0 (full non-membership) and 1 (full membership) [69]. Three anchors are determined as a threshold to define membership scores, i.e., full membership (95th percentile), crossover points (50th percentile), and non-full membership (5th percentile), of the causal conditions and outcomes. Details on the three anchors for each variable in formal and non-formal R&D firms are presented in Tables 2 and 3, respectively. Then, membership scores of the causal conditions and outcomes are calibrated using fs/QCA 3.0 [67].

Table 2. Causal conditions and outcome calibration in formal R&D firms.

Formal R&D	it	er	pd	qcc	cc	sc	pdi1	pdi2	pdi3	pdi4
Frequency	38.000	38.000	38.000	38.000	38.000	38.000	38.000	38.000	38.000	38.000
Std. Deviation	0.384	0.380	0.369	0.457	0.316	0.305	0.276	0.301	0.252	0.371
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000
Median	0.750	0.250	1.000	0.500	0.643	0.571	1.000	1.000	1.000	0.500
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Calibration values at Full non-membership point (5th percentile)	0.000	0.000	0.000	0.000	0.000	0.136	0.475	0.000	0.500	0.000
Crossover point (50th percentile, Mean)	0.625	0.434	0.754	0.513	0.560	0.553	0.789	0.776	0.776	0.566
Full membership point (95th percentile)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: The notation of the variables is presented in Table 1.

Table 3. Causal conditions and outcome calibration in non-formal R&D firms.

Non-Formal R&D	it	er	pd	qcc	cc	sc	pdi1	pdi2	pdi3	pdi4
Frequency	49.000	49.000	49.000	49.000	49.000	49.000	49.000	49.000	49.000	49.000
Std. Deviation	0.381	0.336	0.460	0.451	0.329	0.326	0.307	0.310	0.313	0.357
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Median	0.500	0.000	0.000	0.500	0.286	0.429	1.000	0.500	0.500	0.500
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Calibration values at Full non-membership point (5th percentile)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Crossover point (50th percentile, Mean)	0.469	0.235	0.422	0.490	0.367	0.429	0.724	0.653	0.663	0.551
Full membership point (95th percentile)	1.000	1.000	1.000	1.000	0.929	0.857	1.000	1.000	1.000	1.000

Note: The notation of the variables is presented in Table 1.

3.3.3. Necessity Analysis

A necessity analysis was conducted to identify sufficient and necessary conditions. If the consistency score of a causal condition exceeds the threshold score of 0.9, that causal condition is considered as a necessity condition, where an outcome is a subset of a causal condition; otherwise, it is considered as a sufficient condition, where a causal condition is a subset of an outcome [69]. The high and low levels of internal HRM practices and supply chain collaboration were tested in relation to the high and low levels for each type of product innovation. The results from the necessity analysis indicate that none of the causal conditions exceeded 0.9. Details of the necessity analysis of formal and non-formal R&D firms are presented in Tables 4 and 5, respectively. This means that there are no necessity conditions in formal and non-formal R&D firms. Hence, each type of product innovation is not necessarily caused by a single condition of internal HRM practices and supply chain collaboration.

Table 4. Necessity conditions analysis for formal R&D firms.

Formal R&D		it	~ it	er	~ er	pd	~ pd	qcc	~ qcc	cc	~ cc	sc	~ sc
pdi1	Consistency	0.600	0.483	0.537	0.548	0.750	0.333	0.537	0.545	0.498	0.589	0.515	0.570
	Coverage	0.621	0.681	0.699	0.604	0.661	0.617	0.631	0.662	0.552	0.763	0.623	0.672
~ pdi1	Consistency	0.665	0.459	0.468	0.658	0.693	0.430	0.587	0.534	0.728	0.400	0.588	0.538
	Coverage	0.465	0.436	0.412	0.489	0.412	0.538	0.466	0.438	0.545	0.350	0.480	0.428
pdi2	Consistency	0.630	0.474	0.528	0.578	0.763	0.325	0.538	0.546	0.558	0.566	0.555	0.575
	Coverage	0.728	0.745	0.768	0.711	0.751	0.672	0.705	0.739	0.691	0.817	0.750	0.756
~ pdi2	Consistency	0.676	0.530	0.530	0.681	0.683	0.493	0.616	0.551	0.747	0.500	0.630	0.630
	Coverage	0.391	0.417	0.386	0.419	0.336	0.510	0.404	0.373	0.463	0.362	0.426	0.415
pdi3	Consistency	0.614	0.477	0.558	0.533	0.815	0.276	0.541	0.550	0.583	0.509	0.614	0.476
	Coverage	0.583	0.617	0.666	0.539	0.659	0.469	0.583	0.613	0.592	0.604	0.681	0.514
~ pdi3	Consistency	0.641	0.469	0.448	0.662	0.622	0.489	0.579	0.531	0.596	0.515	0.456	0.652
	Coverage	0.504	0.501	0.443	0.553	0.415	0.686	0.516	0.489	0.501	0.505	0.419	0.583
pdi4	Consistency	0.745	0.422	0.593	0.578	0.798	0.346	0.620	0.531	0.658	0.561	0.706	0.516
	Coverage	0.671	0.517	0.672	0.554	0.611	0.557	0.633	0.560	0.634	0.631	0.743	0.529
~ pdi4	Consistency	0.574	0.606	0.498	0.687	0.703	0.452	0.550	0.613	0.646	0.590	0.504	0.736
	Coverage	0.479	0.688	0.522	0.610	0.499	0.675	0.521	0.599	0.577	0.616	0.491	0.699

Note: The notation of the variables is presented in Table 1.

Table 5. Necessity conditions analysis for non-formal R&D firms.

Non-Formal R&D		it	~ it	er	~ er	pd	~ pd	qcc	~ qcc	cc	~ cc	sc	~ sc
pdi1	Consistency	0.531	0.615	0.371	0.751	0.558	0.541	0.539	0.590	0.395	0.754	0.506	0.649
	Coverage	0.668	0.724	0.674	0.686	0.761	0.593	0.665	0.707	0.620	0.747	0.631	0.771
~ pdi1	Consistency	0.636	0.591	0.468	0.722	0.425	0.729	0.621	0.579	0.605	0.625	0.700	0.541
	Coverage	0.516	0.448	0.548	0.426	0.374	0.516	0.494	0.447	0.613	0.400	0.563	0.414
pdi2	Consistency	0.570	0.614	0.417	0.747	0.590	0.530	0.533	0.611	0.450	0.757	0.542	0.654
	Coverage	0.646	0.651	0.683	0.615	0.726	0.524	0.592	0.660	0.637	0.676	0.608	0.700
~ pdi2	Consistency	0.602	0.622	0.434	0.765	0.416	0.730	0.618	0.555	0.561	0.690	0.660	0.578
	Coverage	0.563	0.544	0.586	0.520	0.423	0.596	0.568	0.495	0.656	0.509	0.612	0.510
pdi3	Consistency	0.568	0.619	0.425	0.713	0.562	0.557	0.554	0.595	0.436	0.763	0.532	0.645
	Coverage	0.652	0.665	0.704	0.595	0.700	0.558	0.624	0.652	0.626	0.690	0.605	0.699
~ pdi3	Consistency	0.611	0.622	0.394	0.778	0.449	0.700	0.603	0.584	0.573	0.675	0.653	0.567
	Coverage	0.563	0.536	0.523	0.520	0.448	0.561	0.544	0.512	0.659	0.490	0.596	0.493
pdi4	Consistency	0.552	0.650	0.446	0.738	0.552	0.559	0.572	0.601	0.426	0.774	0.550	0.652
	Coverage	0.584	0.644	0.682	0.568	0.634	0.516	0.594	0.606	0.564	0.646	0.577	0.651
~ pdi4	Consistency	0.623	0.588	0.412	0.782	0.450	0.666	0.591	0.590	0.556	0.654	0.634	0.578
	Coverage	0.630	0.556	0.600	0.574	0.494	0.587	0.586	0.569	0.701	0.521	0.635	0.551

Note: The notation of the variables is presented in Table 1.

After the calibration and necessity analysis, the datasets were qualified and ready to identify the configurations of internal HRM practices and supply chain collaboration that lead firms to achieve high levels of innovation and cause firms to achieve low levels for each type of product innovation in formal and non-formal R&D firms. The truth tables were generated; they could be refined in accordance with the consistency cutoff and frequency cutoff. The consistency cutoff was set to 0.8, which was the default and minimum value from the software [69]. The software set the default frequency cutoff to 1 [69], but the frequency cutoff was set to 2. This helped to improve the accuracy of configurations for promoting product innovation. Only complex solutions are presented in this study because parsimonious and intermediate solutions make some simplification assumptions on complex solutions [67,69,75].

4. Results and Discussions

4.1. Firm Description

The results show that respondents are mostly locally owned firms; 71.4% and 73.7% of them adopt non-formal and formal R&D, respectively. SMEs (employees < 200) from these responding firms mainly have limited capabilities in human and financial capital, so they adopt non-formal R&D, whereas large firms (employee \geq 200) tend to have higher capabilities to adopt formal R&D for promoting innovation. The descriptive statistics also indicate that non-formal and formal R&D firms mainly have top management as the main mentors for promoting product innovation, which accounts for 75.5% and 73.7%, respectively. Details of the firms' basic information are illustrated in Table 6.

Table 6. Firms' basic information.

Firm Basic Information		Non-Formal R&D (49)		Formal R&D (38)	
		Frequency	Percent	Frequency	Percent
Capital structure of establishment	100% locally-owned	35	71.4	28	73.7
	100% foreign-owned (MNC)	5	10.2	7	18.4
	Joint venture (JV)	9	18.4	3	7.9
	Total	49	100.0	38	100.0
Number of full-time employees	1–19	8	16.3	5	13.2
	20–49	3	6.1	3	7.9
	50–99	10	20.4	7	18.4
	100–199	9	18.4	3	7.9
	200–299	4	8.2	4	10.5
	300–399	3	6.1	0	0.0
	400–499	3	6.1	1	2.6
	500–999	3	6.1	6	15.8
	1000–1499	3	6.1	1	2.6
	1500–1999	1	2.0	2	5.3
	More than 2000	2	4.1	6	15.8
	Total	49	100.0	38	100.0
Main mentors for promoting product innovation	Top Management	37	75.5	28	73.7
	Heads of R&D departments	14	28.6	17	44.7
	Engineers in R&D departments	6	12.2	7	18.4
	Managers of cross-functional teams	5	10.2	6	15.8
	Employees of cross-functional teams	2	4.1	1	2.6
	Engineers in non-R&D departments	3	6.1	2	5.3
	Production line leaders	12	24.5	7	18.4
	Factory workers	6	12.2	5	13.2
	Office workers	3	6.1	1	2.6

4.2. Formal R&D Firms

Various configurations proposed by fs/QCA lead firms to achieve high levels of innovation and cause firms to achieve low levels for each type of product innovation in formal R&D firms (**Hf**). These

configurations range from A1 (pdi1) to D7 (pdi4). The consistency levels of these configurations range from 0.807 (A3) to 1.000 (A5), and the raw coverage of these configurations ranges from 0.124 (A2) to 0.409 (D4). Details of these configurations are presented in Table 7.

Table 7. Configurations of internal human resource management practice and supply chain collaboration in formal R&D firms.

Formal R&D	Antecedent Conditions						Coverage		Consistency	Solution		Cutoff	
	it	er	pt	qcc	cc	sc	Raw	Unique		Coverage	Consistency	Frequency	Consistency
pdi1	A1	○	○	●	○	○	0.241	0.122	0.884	0.368	0.810	2	0.807
	A2	○	○	○	○	●	0.124	0.028	0.844				
	A3	●	○	●	●	○	0.163	0.048	0.807				
	A4	●	●	●	○	○	0.155	0.036	0.919				
~ pdi1	A5	○	○	○	●	●	0.192	0.192	1.000	0.192	1.000	2	1.000
pdi2	B1	○	○	●	○	○	0.236	0.117	0.966	0.383	0.940	2	0.910
	B2	○	○	○	○	●	0.131	0.036	1.000				
	B3	●	○	●	●	○	0.164	0.057	0.910				
	B4	●	●	●	○	○	0.151	0.040	1.000				
~ pdi2	B5	○	○	○	●	●	0.232	0.232	1.000	0.232	1.000	2	1.000
pdi3	C1	○	○	●	○	○	0.256	0.123	0.861	0.355	0.874	2	0.861
	C2	○	○	○	○	●	0.160	0.043	1.000				
	C3	●	●	●	○	○	0.170	0.056	0.927				
~ pdi3	C4	○	○	○	●	●	0.171	0.171	1.000	0.171	1.000	2	1.000
pdi4	D1	○	○	○	○	●	0.187	0.089	0.839	0.606	0.781	2	0.807
	D2	●	○	●	●	○	0.187	0.041	0.807				
	D3	●	●	●	○	○	0.182	0.052	0.937				
	D4	●	●	●	●	●	0.409	0.278	0.813				
~ pdi4	D5	○	○	○	○	○	0.288	0.184	0.862	0.438	0.820	2	0.812
	D6	●	○	●	○	○	0.203	0.095	0.812				
	D7	○	○	○	●	●	0.158	0.051	0.980				

Note: ● indicates the presence of a condition; ○ indicates the absence of a condition; “Blank” indicates the presence or absence of a condition.

Hf: Configurations of internal HRM practices and supply chain collaboration to achieve high levels (pdi) and low levels (~ pdi) for each type of product innovation in formal R&D firms.

The results indicate that firms achieve high levels of product innovation by adopting internal HRM practices, i.e., pdi1 (A1, A3), pdi2 (B1, B3), pdi3 (C1), and pdi4 (D2); or by collaborating with customers and suppliers, i.e., pdi1 (A2), pdi2 (B2), pdi3 (C2), and pdi4 (D1). More specifically, firms achieve high levels for each type of product innovation when there is the presence of R&D personnel development, i.e., pdi1 (A1, A3, A4), pdi2 (B1, B3, B4), pdi3 (C1, C3), and pdi4 (D2, D3, D4). If firms do not adopt R&D personnel development, they need to collaborate with customers and suppliers to achieve high levels for each type of product innovation, i.e., pdi1 (A2), pdi2 (B2), pdi3 (C2), and pdi4 (D1). In addition, firms also achieve high levels for each type of product innovation by combining internal HRM practices (the presence of in-house training, engineer rotation, and R&D personnel development) with supplier collaboration, i.e., pdi1 (A4), pdi2 (B4), pdi3 (C3), and pdi4 (D3).

This means that there are various configurations for promoting each type of product innovation, and firms can do it either internally, through internal HRM practices (especially adopting R&D personnel development); externally, through supply chain collaboration; or by any combination of them. This finding is consistent with that of Nonaka and Takeuchi [25], who assert that firms create new knowledge through initiation and interaction internally with the firm (e.g., trial-and-error, machine learning, group discussions, morning talks, innovation program, and in-house R&D), and/or externally with supply chain partners (e.g., customers, suppliers, universities, and external R&D center). Specifically, Mani [2] highlighted how critical R&D personnel development is in upgrading human resource capabilities and promoting innovation. Intarakumnerd [53] added that if firms can leverage resources from external supply chain partners, they tend to be more successful in promoting innovation because external partners, especially foreign direct investors, tend to embed new knowledge which may not exist domestically.

The results also indicate that firms achieve high levels in producing new products based on new technologies, i.e., pdi4 (D4), if firms adopt every type of internal HRM practice and supply chain collaboration. However, if firms miss out on adopting all these practices, the firms achieve low levels of producing new products based on new technologies—i.e., pdi4 (D5). These results show that formal R&D firms may not need to adopt all HRM practices to achieve the first three types of product innovation, but if they want to achieve the complex type of product innovation, they may need to adopt all the HRM practices. The literature also presents how critical HRM practices are, but it does not mention that missing out on adopting all these practices may cause firms to achieve low levels of product innovation.

Besides this, firms achieve low levels of product innovation if they just adopt quality control circles, customer collaboration, and supplier collaboration without adopting in-house training, engineer rotation, and R&D personnel development—i.e., pdi1 (A5), pdi2 (B5), pdi3 (C4), and pdi4 (D7). This result shows how critical other related practices are to spur quality control circles, customer collaboration, and supplier collaborations for promoting product innovation. Therefore, firms need to have adequate internal capabilities if they want to benefit from customer and supplier collaboration. Scaringella and Burtschell [76] stated that being poor in organizational absorptive capacity may result in unsuccessful knowledge transfer from supply chain partners for promoting innovation. In addition, firms may not achieve adequate benefits from internationalization with supply chain partners if their collaboration linkages are below a threshold of absorptive capacities for knowledge acquisition and knowledge transfer [77].

4.3. Non-Formal R&D Firms

Various configurations, proposed by fs/QCA, lead firms to achieve high levels and low levels for each type of product innovation in non-formal R&D firms (**Hn**). These configurations range from W1 (pdi1) to Z6 (pdi4). The consistency levels of these configurations range from 0.741 (X1) to 0.957 (X7). The raw coverage of these configurations ranges from 0.145 (X4) to 0.340 (W5). Details of these configurations are presented in Table 8.

Table 8. Configurations of internal HRM practices and supply chain collaboration in non-formal R&D firms.

Non-Formal R&D	Antecedent Conditions						Coverage		Consistency	Solution		Cutoff	
	it	er	pt	qcc	cc	sc	Raw	Unique		Coverage	Consistency	Frequency	Consistency
pdi1	W1	•	○	○	○	○	0.225	0.088	0.873	0.521	0.854	2	0.851
	W2	○	○	•	○	○	0.253	0.169	0.889				
	W3	•	•	○	○	○	0.166	0.023	0.941				
	W4	•	•	•	•	•	0.190	0.096	0.861				
~ pdi1	W5	•	•	○	•	•	0.340	0.191	0.925	0.364	0.876	2	0.841
	W6	•	•	○	•	○	0.173	0.024	0.841				
pdi2	X1	○	○	○	○	○	0.328	0.164	0.741	0.662	0.745	2	0.801
	X2	○	○	•	○	○	0.266	0.139	0.841				
	X3	•	•	○	○	○	0.181	0.029	0.926				
	X4	•	○	○	•	•	0.145	0.029	0.836				
	X5	•	•	•	•	•	0.218	0.102	0.892				
~ pdi2	X6	•	○	•	•	•	0.295	0.166	0.924	0.336	0.932	2	0.918
	X7	•	•	○	•	○	0.171	0.041	0.957				
pdi3	Y1	○	○	•	○	○	0.287	0.194	0.921	0.483	0.872	2	0.873
	Y2	•	•	○	○	○	0.175	0.075	0.905				
	Y3	•	•	•	•	•	0.214	0.111	0.886				
~ pdi3	Y4	•	○	○	•	•	0.274	0.140	0.846	0.411	0.765	2	0.813
	Y5	•	○	○	○	○	0.251	0.116	0.820				
	Y6	•	•	○	•	○	0.152	0.001	0.841				
pdi4	Z1	•	•	○	○	○	0.191	0.082	0.910	0.421	0.802	2	0.804
	Z2	○	○	•	•	○	0.181	0.079	0.897				
	Z3	•	○	○	•	•	0.149	0.039	0.804				
	Z4	•	•	•	•	•	0.219	0.098	0.835				
~ pdi4	Z5	•	○	•	•	•	0.265	0.145	0.895	0.303	0.907	2	0.883
	Z6	•	•	○	•	○	0.158	0.038	0.957				

Note: • indicates the presence of a condition; ○ indicates the absence of a condition; “Blank” indicates the presence or absence of a condition.

Hn: Configurations of internal HRM practices and supply chain collaboration to achieve high levels (pdi) and low levels (~ pdi) for each type of product innovation in non-formal R&D firms.

The results indicate that firms achieve high levels of redesigning packaging or significantly changing appearance design, i.e., pdi1 (W1), and significantly improving current products, i.e., pdi2 (X1), even with or without adopting in-house training. However, if firms just adopt in-house training without adopting other types of practices, they may result in low levels of producing new products based on current technologies, i.e., pdi3 (Y6). In addition, it is common that if firms are able to adopt every HRM practice, they can achieve high levels for each type of product innovation—i.e., pdi1 (W4), pdi2 (X5), pdi3 (Y3), and pdi4 (Z4). This means that non-formal R&D firms also realized how critical internal efforts and external collaboration are in promoting product innovation. This is also consistent with Nonaka and Takeuchi [25], where sources of knowledge for promoting innovation can be created internally through employee interactions and externally through collaboration with supply chain partners. However, non-formal R&D firms are mostly SMEs, as presented in the descriptive statistics. They have limited financial resources, low technological capabilities, insufficient infrastructure, and low managerial skills [35]. Even though they understand the benefits of collaboration—e.g., pools of knowledge for problem-solving, places for knowledge sharing and integration, increase choices for decision making, and enhance learning within and across an organization [14]—they mostly try to achieve high levels of product innovation internally without customer and supplier collaboration, i.e., pdi1 (W2, W3), pdi2 (X3, X4), pdi3 (Y1, Y2), pdi4 (Z1, Z2). This shows firms' innovativeness in utilizing existing resources to promote product innovation.

Besides, firms result in low levels for each type of product innovation if they just adopt in-house training, quality control circles, customer collaboration, and supplier collaboration, without adopting engineer rotation and R&D personnel development—i.e., pdi1 (W5), pdi2 (X6), pdi3 (Y4), and pdi4 (Z5). This also happens if they just adopt in-house training, engineer rotation, and quality control circles, without adopting R&D personnel development, customer collaboration, and supplier collaboration—i.e., pdi1 (W6), pdi2 (X7), pdi3 (Y5), and pdi4 (Z6). Therefore, there are various configurations that cause firms to result in low levels for each type of product innovation. Specifically, these configurations show that adopting in-house training without R&D personnel development always cause firms to result in low levels for each type of product innovation even with or without customer and supplier collaboration.

4.4. Cross-Comparison between Formal and Non-Formal R&D Firms

The results indicate that formal and non-formal R&D firms achieve high levels of product innovation by adopting internal HRM practices or collaborating with customers/suppliers. They still can achieve high levels of product innovation if they adopt both simultaneously. This means that there are various configurations for promoting product innovation, and firms adopt those configurations based on their capabilities. For example, large firms tend to have higher capabilities in human resources, technological knowledge, and financial capital, so they invest in R&D [48,49]; they possess innovative advantages over SMEs [50]. This also shows the firm's innovativeness in promoting product innovation by using existing resources, because new knowledge is created through internal interaction within the firm and/or co-created through external collaboration with supply chain partners [25].

In addition, formal R&D firms also achieve high levels of product innovation if they adopt R&D personnel development. If firms do not adopt R&D personnel development, they need to collaborate with customers and suppliers to achieve high levels of product innovation. However, non-formal R&D firms show the presence and an absence of R&D personnel development on configurations to achieve high levels of product innovation. This cannot make us draw any conclusions on the roles of R&D personnel development in achieving high levels of product innovation, but the results indicate that the absence of R&D personnel development causes non-formal R&D firms to result in low levels of product innovation. There is no adequate evidence to make conclusions on the roles of in-house training, engineer rotation, and quality control circles in formal and non-formal R&D firms, because it

somehow leads firms to achieve high levels low levels of product innovation. This does not mean that they are not important for promoting product innovation, but R&D personnel development tends to be more critical in the Thai manufacturing context.

Formal R&D firms result in low levels of product innovation if they just adopt quality control circles, customer collaboration, and supplier collaboration without in-house training, engineer rotation, and R&D personnel development. Whereas, non-formal R&D firms result in low levels of product innovation if they just adopt in-house training without R&D personnel development, even with or without customer and supplier collaboration. Across these two groups, both groups proved that an absence of R&D personnel development causes firms to result in low levels of product innovation. Mani [2] specifically highlighted how critical R&D personnel development is in upgrading human resources capabilities and promoting innovation, but he did not mention that missing out on adopting R&D personnel development may cause firms to result in low levels of product innovation.

5. Conclusions

The sources of knowledge for promoting innovation tend to vary from one context to another. This led us to conduct an empirical study to identify the configurations of internal HRM practices and supply chain collaboration that lead firms to achieve high levels and cause firms to result in low levels for each type of product innovation in formal and non-formal R&D firms. The data were collected during the period December 2016–February 2017 from manufacturing firms located in the Bangkok metropolitan area. The target respondents were the key people in managerial positions—e.g., presidents, chief executive officers, directors, managers, heads of departments, and group leaders—because they have adequate knowledge for answering our questionnaire. In total, 87 respondents were included for an empirical fuzzy-set quality comparative analysis.

The results provide various configurations with the following commonality across formal and non-formal R&D firms. First, formal and non-formal R&D firms can achieve high levels of product innovation by adopting internal HRM practices or collaborating with supply chain partners, and these highly depend on their capabilities. Formal and non-formal R&D firms also achieve high levels of product innovation if they adopt both simultaneously. Second, formal R&D firms achieve high levels of product innovation if there is the presence of R&D personnel development. If firms do not have R&D personnel development, they need to collaborate with customers and suppliers to achieve high levels of product innovation. However, non-formal R&D firms do not show the critical role of R&D personnel development, since it is present in and also absent from configurations to achieve high levels of product innovation. Finally, formal R&D firms result in low levels of product innovation if they just adopt quality control circles, customer collaboration, and supplier collaboration, without adopting in-house training, engineer rotation, and R&D personnel development. Whereas, non-formal R&D firms result in low levels of product innovation if they just adopt in-house training with the absence of R&D personnel development, even when there is the presence or absence of customer and supplier collaboration. Across these two groups, the results prove that missing out on adopting R&D personnel development causes firms to result in low levels of product innovation. Therefore, various configurations lead firms to achieve high levels and cause firms to result in low levels for promoting product innovation in formal and non-formal R&D firms. These configurations may not be the best HRM practices for promoting product innovation, but they are the best fits in the Thai manufacturing context.

6. Practical Implication, Limitations, and Further Studies

Firms mainly adopt HRM practices based on their own capabilities. Large firms tend to have stronger capabilities to invest in formal R&D [48,49] and possess innovative advantages over smaller firms in terms of heterogeneous R&D activities [50]. Therefore, top management needs to realize their firm technological capabilities, whether it is formal or non-formal R&D [52,53], such that they can adopt appropriate HRM practices in accordance with the firm technological capabilities to promote

product innovation. The results from this study show that R&D personnel development helps formal R&D firms to achieve product innovation, whereas quality control circles do not. This is different from non-formal R&D firms, where there is not enough evidence to prove the importance of R&D personnel development, but quality control circles somehow help non-formal R&D firms to achieve product innovation. Additionally, the results show that collaboration with customers and suppliers is the best configuration for promoting product innovation in formal R&D forms, but these collaborations seem to be less significant if they are in non-formal R&D firms. Therefore, any types of HRM practices are beneficial in their own ways to promote product innovation if the top management is able to identify related complementary HRM practices.

There are three main limitations; first, the results may only represent manufacturing firms in emerging economies, e.g., Thailand, because firms in these countries mainly have low internal capabilities and adopt top-down management systems for promoting innovation. This may be different from developed nations—e.g., Japan, the US, or EU countries—where firms mainly have high capabilities and may adopt bottom-up or middle-up-down management systems for promoting innovation. Second, a fuzzy-set quality comparative analysis was used to identify the configurations of causal conditions that achieve high levels and low levels of outcomes. These configurations were identified in accordance with the provided causal conditions and outcomes. Thus, the results in this study are limited to the internal HRM practices and supply chain collaboration presented in this research. Additional causal conditions may lead to variations in configurations for promoting product innovation. Third, firms may share the same configurations to achieve high levels and low levels of product innovation. These conflicts can be solved by making assumptions about complex solutions to achieve intermediate and parsimonious solutions. However, this study presents only complex solutions, and we mainly make conclusions on the conditions presented in every configuration for achieving high levels low levels of each type of product innovation.

For further studies, first, this study could be conducted in the context of firms located in developed countries where local firms have high capabilities in human and financial capital. Results may provide us with different perspectives on the significance of internal HRM practices and supply chain collaboration for promoting product innovation in formal and non-formal R&D firms. Second, this research can also be expanded to countries that adopt bottom-up and middle-up-down management systems for promoting innovation. This is because different management systems lead firms to adopt different practices for creating knowledge and promoting innovation. Besides giving information on the manufacturing industry in emerging economies, this study can be expanded to study practices for promoting product innovation in the service and agricultural industries. In addition, other types of innovation—e.g., process, technological, marketing, and position innovation—can be investigated because different practices may be required to achieve these innovations.

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