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Coordination of Internal and External Human Resource Management for Upgrading Firm Technological Capabilities in the Context of Manufacturing Firms in Thailand

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Japan Advanced Institute of Science and Technology

Doctoral Dissertation

Coordination of Internal and External Human Resource Management for Upgrading Firm Technological Capabilities in the Context of Manufacturing Firms in Thailand

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ABSTRACT

Understanding human resource management (HRM) practices based on the contexts are crucial for an organisation to provide appropriate solutions for technology upgrading and innovation. Arnold et al. (2000) defined four stages of firm technological capabilities; i.e., technology use and operation, technology acquisition and assimilation, technology upgrading and reverse engineering, and research and development (R&D); arranging them in ascending order of difficulties. In their study, they defined states of firms for each stage, but they did not identify coordination of internal and external HRM practices to upgrade firm technological capabilities for one stage to another. This deficiency leads us to adopt qualitative analysis to identify coordination of internal and external HRM practices to upgrade firm technological capabilities in the context of manufacturing firms in Thailand.

The results from the qualitative analysis indicate that to be on the first stage of technology use and operation, firms need to adopt internal training and collaborate with suppliers and related partners for plant setup and operation. Then firms need specific recruitment procedures and precise training and development plans so that they can move to the second stage of technology acquisition and assimilation. Also, firms need to adopt cross-functional teams and project-based teams before they can upgrade to the third stage of technology upgrading and reverse engineering. Lastly, firms need key R&D gurus, e.g., highly qualified personnel with master and Ph.D. degrees, from internal and external sources to upgrade their capabilities to the last stage of R&D. The results from case studies provide us insight knowledge on coordination of internal and external HRM practices to upgrade firm technological capabilities from the fundamental stage of technology use and operation to the complex stage of R&D.

Knowledge from case analysis motivates us to proceed with further empirical study. From the literature review, researchers mainly study effects of HRM practices on innovation and performance. Although relationships between HRM practices and innovation have been extensively studied, these relationships have not been fully understood. Researchers have not identified precise configurations of HRM practices and main mentors for promoting product innovation across different stages of firm technological capabilities. They mainly generalised conclusions through conventional methods by analysing effects or relationships of a single or group of variables on an outcome. Results from these studies may not fully represent and explain, where different combinations of HRM practices may lead to a presence or an absence of innovation. Also, researchers do not compare configurations of HRM practices for

promoting product innovation across different stages of firm technological capabilities, e.g., formal R&D firms – firms that allocated at least some portions of their sale budgets for the purpose of R&D – and non-formal R&D firms. These deficiencies lead us to adopt fuzzy-set qualitative comparative analysis (fs/QCA) to identify configurations of HRM practices and main mentors that lead firms to achieve high levels and cause firms to result in low levels of product innovation across different stages of firm technological capabilities.

The results from the empirical fs/QCA are presented in formal and non-formal R&D firms, where the former indicate four main findings, i.e., (1) R&D personnel development helps formal R&D firms to achieve high levels of product innovation, and if formal R&D firms do not adopt R&D personnel development, they need to collaborate with customers and suppliers; (2) QCCs do not help formal R&D firms to achieve high levels of product innovation, but it is somehow helpful after including supply chain collaboration; (3) QCCs cause formal R&D firms to result in low levels of product innovation. Even with a presence of customer and supplier collaboration in addition to QCCs, formal R&D firms still result in low levels of product innovation if they do not adopt in-house training, engineer rotation, and R&D personnel development; and (4) top management is the main mentors for promoting product innovation, and s/he needs to work with heads of R&D departments.

The latter results on non-formal R&D firms also indicate four main findings, i.e., (1) there is no enough evidence to prove how important R&D personnel development is in helping firms to achieve high levels of product innovation even with a presence or an absence of customer and supplier collaboration; (2) QCCs are somehow helpful for non-formal R&D firms as shown before and after including supply chain collaboration; (3) non-formal R&D firms result in low levels of product innovation if there is an absence of R&D personnel development. Even with a presence or an absence of customer and supplier collaboration, non-formal R&D firms still result in low levels of product innovation if firms do not adopt R&D personnel development; and (4) top management is the main mentors for promoting product innovation, and s/he needs to work with managers of cross-functional teams.

The results from the qualitative analysis and fs/QCA contribute to the literature review by, first, identifying coordination of HRM practices to upgrade firm technological capabilities in the context of manufacturing firms in Thailand. Second, firms should adopt R&D personnel development such that they can achieve more product innovation. If firms do not adopt R&D personnel development, they should at least collaborate with customers and suppliers to acquire new knowledge for promoting innovation. Even some configurations in non-formal R&D firms do not show precise evidence on the significance of R&D personnel development, firms mainly result in low levels of product innovation if they do not adopt R&D personnel development. Third, adopting only QCCs may cause firms to result in low levels in promoting product innovation, so firms should adopt other related practices, e.g., in-house training, engineer rotation, R&D personnel development, or collaborate with supply chain partners. Fourth, the top-management is recognised as the main mentors for promoting innovation, and this study proves that the top management needs to work with heads of R&D departments for formal R&D firms and managers of cross-functional teams for non-formal R&D firms.

For practical implication, first, the managers need to understand the technological capabilities of their firms so that they can introduce appropriate HRM practices for technology upgrading and innovation. Second, understanding the best HRM practices from the global context is useful, but the managers should not fully adopt those practices. They need to find the best fits of HRM practices in accordance with the current states of their firm. Third, pathways for promoting innovation across different stages of firm technological capabilities can occur through various configurations, so understanding the right combination of HRM practices could help firms for technology upgrading and innovation. Fourth, knowledge sharing from related personnel in various positions within the organisation does not cause firms to result in low levels of innovation, so the managers should motivate their employees to join in innovative activities for knowledge sharing and knowledge co-creation.

Keywords: Case studies; formal R&D; fuzzy-set qualitative comparative analysis; human resource management practices; main mentors; non-formal R&D; supply chain collaboration; technological capabilities; innovation

DEDICATION

This dissertation is exceptionally dedicated to my beloved grandmothers (LAI HEANG and KEA NAI), although they are no longer with us. Moreover, it also dedicates to my parents, brothers, sisters, nieces, and nephews.

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LIST OF SYMBOLS/ABBREVIATIONS

Symbols/Abbreviations	Terms
C-ChEPS	Constructionism Chemicals Engineering Practice School
CEO	Chief Executive Officer
CU	Chulalongkorn University
ERIA	Economic Research for ASEAN and East Asia
EU	European Union
Fs/QCA	Fuzzy-set Qualitative Comparative Analysis
GGC	Global Green Chemical Public Company Limited
HRM	Human Resource Management
KPI	Key Performance Indicator
ISO	International Organisation for Standardisation
JVs	Joint Ventures
MNCs	Multinational Companies
MRS	Major Research Questions
NSTDA	National Science and Technology Development Agency
OBM	Original Brand Manufacturing
POSITIVE	Professional approach, Ownership and commitment, Social responsibility, Integrity, Teamwork and collaboration, Initiative, Visionary focus, and Excellent striving.
PTTGC	PTT Global Chemical Company Limited
QCA	Qualitative comparative analysis
QCCs	Quality Control Circles
R&D	Research and Development
SCG Chemical	Siam Cement Group Chemicals Company Limited
SECI	Socialisation, Externalisation, Combination, and Internalisation
SMEs	Small and Medium Enterprises
SPEED	Source by expanding channels to recruit new applicants, Partnership by establishing partnerships with academic institutions, Employer brand by providing equal opportunities to employees to be promoted, Employee referral by providing

	incentives to employees for recommended qualified applicants, and Driving fast recruitment by improving and fastening recruitment and selection process.
SRQ	Sub Research Questions
STAR	Situation, Task, Action, and Result
Thai Oil	Thai Oil Public Company Limited
USA	United State of America
4B	Building by recruiting new graduates, Buying by hiring young and talented candidates, Borrowing by asking support from supply chain partners, and Bring-in by making contract-based employment

LIST OF SYMBOLS USED IN FS/QCA

Symbols/Abbreviations	**Terms**
it	In-house training
er	Engineer rotation
pd	R&D personnel development
qcc	Quality control circles
sc	Supplier collaboration
cc	Customer collaboration
tm	Top management
hrdd	Heads of R&D departments
erdd	Engineers in R&D departments
mct	Managers of cross-functional teams
ect	Employees of cross-functional teams
enrdd	Engineers in non-formal R&D departments
pll	Production line leaders
fw	Factor workers
ow	Office workers
pdi1	Product innovation type 1, which is redesigning packaging or significantly changing appearance design.
pdi2	Product innovation type 2, which is significantly improving current products.
pdi3	Product innovation type 3, which is producing new products based on existing technologies.
pdi4	Product innovation type 4, which is producing new products based on new technologies.

CHAPTER 1
INTRODUCTION

Overview: This chapter gives an overview of the dissertation, consists of research background to view human resource management (HRM) practices from various contexts, problem statement to highlight gaps to proceed further case and empirical analysis, research objective to achieve and research questions to respond in the dissertation, research significance for academic contribution and practical implications, and dissertation outline to give brief information for each chapter.

1.1 Research background

HRM is the main ingredient for the success or failure of an organisation (Laursen & Foss, 2014). HRM is defined as the strategic approach, in which firms adopted to manage and enhance employee capabilities so that firms can promote innovation, upgrade their capabilities, enhance performance, and stay competitive in the business. HRM is also considered as the assets, where proper alignment and implementation of HRM can enhance knowledge, skill, abilities, and commitment of employees, and result in improving competitive advantages (Barney, 1991; Chowhan, Pries, & Mann, 2016; Huselid, 1995; Kianto, Sáenz, & Aramburu, 2017; Longoni & Cagliano, 2016). For instance, firms mainly have specific recruitment and selection procedures to recruit talented candidates. Then firms provide employee orientation tours to assist newly recruited employees to get familiar with the firm's working environment. Some firms provide regular internal and external training to develop capabilities of the current and new recruited employees. Highly qualified employees are promoted to a higher position through career path development. Thus, HRM composes of policies to support firms for promoting mutual goals, respect, rewards, and responsibility (Walton, 1985).

HRM has got attention from practitioners and academics (Porter, 1985), and has been extensively studied across continents, countries, and industries (Bello-Pintado, 2015; Monks et al., 2016; Tsang, 1999; Tsuji et al., 2017b). For example, Bello-Pintado (2015) identified effects of HRM practices on firm performance using data from the manufacturing firms in Latin American. Similarly, Monks et al. (2016) studied relationships between HRM practices and knowledge exchange among knowledge workers using data from the pharmaceutical sectors in Ireland and the UK. In Japan, Tsuji et al. (2017b) characterised R&D and human resource development of the manufacturing firms by conducting case studies with three Japanese firms.

In Southeast Asia, researchers from Laos (Norasingh & Southammavong, 2017), Vietnam (Binh & Linh, 2017), the Philippines (Del Prado & Rosellon, 2017), Singapore (Tsang, 1999), Indonesia (Aminullah et al., 2017), and Malaysia (Mohan, 2017) identified types of HRM practices in manufacturing firms using qualitative approaches. Researchers on HRM cover various internal and external coordination of HRM practices based on the context of each country. For instance, Aminullah et al. (2017) identified HRM practices to improve skill, knowledge, and abilities of employees through case studies of herbal firms in Indonesia; Norasingh and Southammavong (2017) identified managerial HRM practices and organisational coordination for promoting innovation by studying handicraft firms in Laos; and Binh and Linh (2017) identified HRM practices for promoting innovation by studying electronics firms in Vietnam.

There are various HRM practices, but there is no one best HRM practice, which is applicable in every context. Researchers mainly believe that claiming the best practices of HRM was an overstatement (Purcell, 1999). Proper alignment of HRM practices based on our context is more critical than adopting the best practices from an outside context (Wutthirong & Noknoi, 2009). Newell et al. (2009) believe that a single best practice of HRM in one context may cause problems in managing employees in another context if the managers entirely adopt the same practices without understanding contexts of business operation, culture, norm and value of employees. The limitation of best practices leads researchers to identify the best fit of HRM practices based on their context. Thus, instead of finding the best practices, this is worth finding the right fit of HRM practices based on firm technological capabilities and the context of business operation.

1.2 Problem statement

Understanding HRM practices based on the context is crucial in making senses of what happens in an organisation and provides appropriate solutions for promoting innovation (Cooke, 2018). This is because firms from different contexts, e.g., manufacturing and service industry, developed and developing countries, and SMEs and large firms, adopt different types of HRM practices for technology upgrading and innovation (van Uden, Knoben, & Vermeulen, 2017). What is best for an organisation may result differently from expectation for another organisation (Hendriks, 2003). Also, decisions of HRM practices for technology upgrading and innovation change over time and across different stages of firm growth (Eiriz, Faria, & Barbosa, 2013).

Arnold et al. (2000) defined four stages of firm technological capabilities, i.e., technology use and operation, technology acquisition and assimilation, technology upgrading and reverse engineering, and R&D. In their studies, they defined the states of firms for each stage of firm technological capabilities, but they did not identify HRM practices and coordination of internal and external HRM practices to create new knowledge for technology upgrading from one stage to another. We believe that the role of skill and tacit knowledge differ across firms and countries depending on firm technological capabilities. This leads us to conduct qualitative analysis to identify HRM practices and coordination of internal and external HRM practices for upgrading firm technological capabilities in the context of manufacturing firms in Thailand.

Knowledge from case studies motivates us to proceed further empirical fs/QCA. From an intensive literature review, researchers mainly investigate relationships between HRM practices and innovation. For example, Ueki (2017) combined data from Thailand, Laos, and Vietnam to investigate roles of top management, HRM practices, and customer relationships, for promoting innovation in non-formal R&D firms. Results from the regression analysis indicated that HRM practices highly associate with process innovation, customer relationships significantly correlate with product innovation, and top management contributes to product innovation by mentoring relationships with and among engineers. Similarly, Zhang et al. (2016) identified whether innovation is a mechanism between HRM practices and firm performance. Glaister et al. (2018) studied how firm performance is affected by HRM practices, e.g., training and development, recruitment and selection, workforce planning, and performance appraisal. Results indicated that talent management practices, i.e. work-based systems, international assignment, career portfolio building, and HRM systems, mediate relationships between HRM practices and firm performance.

Although relationships among HRM practices and innovation has been extensively studied in empirical analysis, these relationships have not been fully understood. Researchers have not identified precise configurations of HRM practices and main mentors that help firms to achieve high levels and cause firms to result in low levels of product innovation. They mainly generalised conclusions through conventional methods over sources for promoting innovation. They simply analyse effects or study relationships of a single/group of variables on an outcome. Results from these studies may not fully represent, explain, or cover what happens in workplaces, where different combinations of causal conditions lead firms to achieve different outcomes. Also, researchers do not compare configurations for promoting product innovation between formal R&D firms – firms that allocated at least some portions of their sale budgets for the purpose of R&D – and non-formal R&D firms. These deficiencies lead us to identify configurations of HRM practices and main mentors that lead firms to achieve high levels and cause firms to result in low levels of product innovation across different stages of firm technological capabilities.

1.3 Research objective and questions

The role of skill and tacit knowledge for promoting innovation and upgrading technological capabilities differ across firms and countries, where large firms tend to have stronger capabilities to invest in formal R&D (Intarakumnerd, Chairatana, & Tangchitpiboon, 2002; Petsas & Giannikos, 2005) and possess innovative advantages over smaller firms in terms of heterogeneous R&D activities (Choi & Lee, 2017). Local firms in emerging economies, especially SMEs, have limited financial resources, low technological capabilities, insufficient infrastructure, and low managerial skill (Sudhir Kumar & Bala Subrahmanya, 2010). They are mainly incapable of investing in formal R&D, but they may adopt non-formal practices, e.g., small group activities, in-house training, working with customers and suppliers, for promoting innovation and upgrading their technological capabilities. This leads us to conduct in-depth case studies to identify HRM practices and coordination of internal and external HRM practices for upgrading firm technological capabilities in the context of manufacturing firms in Thailand. Then we adopt empirical fs/QCA to identify configurations of HRM practices and main mentors that help firms to achieve high levels and cause firms to result in low levels of product innovation in formal and non-formal R&D firms. The Major Research Question (MRQ) and Sub Research Questions (SRQs) are presented as follows.

MRQ: What types of HRM practices can be sources for upgrading firm technological capabilities in the Thai manufacturing context? how and why?

SRQ1: What types of HRM practices are needed to upgrade firm technological capabilities?

SRQ2: How and when firms adopt HRM practices to upgrade their technological capabilities, e.g., from non-formal R&D – firms that do not actively engage in systematic innovation, do not established an R&D department, and/or do not allocate budgets for R&D intention – to formal R&D?

SRQ3: How firms combine internal and external HRM practices to promote innovation when they base in different stages of technological capabilities?

SRQ4: Who are the main mentors to manage human resources for innovative activities across different stages of firm technological capabilities?

1.4 Research significance

The results contribute to academics by providing a theoretical model of HRM practices needed to upgrade firm technological capabilities in the context of manufacturing firms in Thailand. This study also provides configurations of HRM practices and main mentors that lead firms to achieve high levels and cause firms to result in low levels of product innovation across different stages of firm growth. For practical implications, this study provides a comprehensive framework to help local firms, especially firms with limited capabilities in financial/human capital and still adopt non-formal practices to upgrade their technological capabilities through internal and external coordination of HRM practices.

1.5 Dissertation outline

This dissertation consists of seven chapters, and it is organised as follows: Chapter 1: introduction, Chapter 2: theoretical background, Chapter 3: research methodology, Chapter 4: HRM practices for upgrading firm technological capabilities, Chapter 5: configurations of HRM practices and main mentor for promoting product innovation, Chapter 6: discussions, and Chapter 7: conclusions.

Chapter 1: Introduction provides an overview of this dissertation, consists of research background, problem statement, research objective and questions, research significance, and dissertation outline.

Chapter 2: Theoretical background reviews knowledge-based view, HRM practices, internal coordination of HRM practices within the firms, external collaboration with supply chain partners, main mentor for promoting innovation, firm technological capabilities, innovation, and Thai manufacturing context.

Chapter 3: Research methodology presents the mixed methodology, comprises of qualitative analysis and qualitative comparative analysis. The former is adopted to conduct in-depth case studies with three manufacturing firms. The latter is adopted to identify configurations of HRM practices and main mentors that lead firms to achieve high levels and cause firms to result in low levels of product innovation in formal and non-formal R&D firms.

Chapter 4: HRM practices for upgrading firm technological capabilities is conducted by using qualitative study. We conduct in-depth interviews with three manufacturing firms, i.e., Thai Oil Public Company Limited, Global Green Chemicals Public Company Limited, and Siam Cement Group Chemicals Company Limited. These three cases are interviewed to identify their HRM practices and coordination of internal and external resources to upgrade firm technological capabilities. The cross-case comparison is conducted to figure out commonalities and differences. Then conclusions on case studies are recapped.

Chapter 5: Configurations of HRM practices and main mentors for promoting product innovation across different stages of firm growth are identified by using qualitative comparative analysis. There are three steps of analysis in this chapter. First, we identify configurations of internal HRM practices that help 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. Second, the supply chain collaboration is included in addition to internal HRM practices to identify configurations. Third, we configure the main mentors for promoting product innovation. Results from the empirical study are recapped for the conclusion.

Chapter 6: Discussions present findings from the qualitative analysis and qualitative comparative analysis. Then we summarise findings by responding to the SRQs and MRQ.

Chapter 7: Conclusions highlight theoretical implications, practical implications, governmental recommendation, limitations, and directions for future studies.

CHAPTER 2
THEORETICAL BACKGROUND

Overview: This chapter presents an intensive literature review on knowledge-based view, HRM practices, internal HRM practices, external collaboration, main mentors for promoting innovation, firm technological capabilities, innovation, and Thai manufacturing context.

2.1 Knowledge-based view

Knowledge is the core value to maintain the survival and growth of an organisation in today's fast-changing business environment. Knowledge is embedded in humans, and it can be developed, applied, and utilised to improve and enhance efficiency and effectiveness in the workplace (Newell et al., 2009). Knowledge is abilities to discriminate within and across context, so it is (1) equivocal which is subjected to different meanings and interpretations, (2) dynamic, where accepted meanings can change as actors and contexts change, and (3) context-dependent, where it is difficult to separate from the context in which it is produced (Clegg & Bailey, 2007). Therefore, knowledge needs to be studied by looking from various contexts (Tsoukas & Vladimirou, 2001).

From the knowledge-based view, Nakamori (2011) presents a knowledge-based society – a society where knowledge and skill are generated and used for the benefits and prosperity of human-being. The competitiveness in the knowledge-based society is high, so firms need to continuously innovate by collecting, synthesising, coordinating, and creating new knowledge so that they can stay competitive to survive and grow. Firms with limited skill and knowledge tend to lack behind their competitors. Nakamori (2011) introduced several key domains in the knowledge-based society, i.e., knowledge technology, knowledge management, knowledge discovery, and knowledge synthesis, knowledge justification, and knowledge construction.

Among these contexts, knowledge is presented in a pyramid to illustrate hierarchical relationships with data, information, and wisdom, where (1) data is a discrete physical entity and have no values on its own; (2) information is interconnected or organised data with recognisable pattern; (3) knowledge is a personal belief or knowing of an individual on data and/or information by drawing from his/her own subjective experiences, perception and understanding; and (4) wisdom is an application of personal knowledge in real life (Ackoff, 1989). This is how knowledge is presented and possessed by every individual. Being able to make sense of words and sentences is knowledge, even if those words or sentences are true or not. Hence, knowledge interpretation is ambiguous because people experience different things, so they may interpret the same information differently.

Knowledge can be new for a firm, new for a market, new for a country, or new to the world, and it is categorised into two groups, i.e., explicit and tacit (Nonaka & Konno, 1998; Nonaka & Takeuchi, 1995). Explicit knowledge is defined as knowledge that can be documented in words/numbers, shared in a form of data/manual, and expressed consciously. Tacit knowledge refers to knowledge that is rooted deeply in individual's actions or experiences as well as ideals, values, and emotion that s/he embraces, and humans sometimes express tacit knowledge unconsciously (Nonaka & Konno, 1998). Tacit knowledge is the know-how knowledge, where it resides and embeds in our body and practical skill, so "We can know more than we can tell" (Polanyi, 1958). Explicit and tacit knowledge always exists in an organisation, where firms mainly socialise, externalise, combine, and internalise them in a spiral process to create new knowledge (Nonaka & Konno, 1998).

2.1.1 "Ba" and knowledge creation process

The spiral process of knowledge creation mainly occurs through various spaces or 'ba' – a concept originally developed by the Japanese philosopher Kitaro Nishida, refers to 'a context which harbours meaning'. Space or 'ba' is an environment, which is used to co-create new knowledge. Space or co-working space occurs in various forms, e.g. quality-control circles, group discussions, informal meetings, formal meetings, and problem-solving (Nonaka & Takeuchi, 1995). These co-working spaces spur knowledge by chance or on purpose from every individual in an organisation. Emerged knowledge, which is created on purpose, tends to be well documented for further knowledge exploration and exploitation. However, emerging knowledge, which is created by chance, tends to be forgotten because an individual, group, or organisation does not know how to use newly emerged knowledge and no platform to store such knowledge. Thus, firms need to have precise objectives, and such objectives need to be shared with every individual inside an organisation (Nonaka et al., 2008).

Nonaka and Konno (1998) defined four types of 'ba' by mapping with SECI knowledge creation model, i.e., (1) originating 'ba' – a place where an individual shares feelings, emotions, and experiences with individual in a non-formal way, and it highly relies on face-to-face contact outside an organisation, e.g., sharing problems and complaints during breaking time; (2) interacting 'ba' – a place where every individual are allocated for a specific project, gathered as a group for dialogue and ideas exchange for problem-solving and project development, e.g., a morning assembly for each division to share problems and propose solutions; (3) cyber 'ba' – a virtual place where every individual could share, compromise, create, and exploit new knowledge throughout the organisation, e.g., using informational and communication technologies to share on, search from, or store in database of an organisation; and (4) exercising 'ba' – a place where knowledge is applied through active participation from every individual, e.g., on-the-job-training, developing training to implement projects, and small group activities. Thus, 'ba' are critical for socialisation, externalisation, combination, and internalisation.

From the knowledge-based view, therefore, knowledge is created and co-created through SECI model from the various 'ba', i.e., physical 'ba' (entity-based, e.g., office, working space, restaurants), virtual 'ba' (media-based, e.g., e-mail, videoconference, internet), mental 'ba' (imaginary-based, e.g., experiences and idea sharing), or the combinations of 'ba', at individual, group, and/or organisation levels (Nonaka & Konno, 1998). Firms mainly cannot create new knowledge by itself without (1) interaction internally within the firms, e.g., trial-and-error, machine learning, group discussions, morning talks, innovation program, and in-house R&D, (2) externally collaboration with supply chain partners, e.g., customers, suppliers, universities, and external R&D centre, or (3) ideas initialisation from the top management and other related individuals (Nonaka & Takeuchi, 1995). Proper adoption of these practices in accordance with the context help firms to become a learning organisation (Marquardt, 2002).

2.1.2 Learning organisation

Firms cannot just invest in new machinery or technologies to improve the efficiency and effectiveness in their organisation, they need to invest in quality control circles (QCCs) or small group activities for problem-solving (Watanabe, 1991). These practices could help firms to grow steadily and become a learning organisation. Senge (1990) defined learning organisations on page three as "organisations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together". This definition could be simplified as firms that facilitate every member to continuously develop themselves for knowledge acquisition and knowledge co-creation (Pedler, Burgoyne, & Boydell, 1991). Firms need to become a learning organisation because there is a rapid change among human behaviour and business environment. Only firms with high flexibility, high adaptability, and high efficiency could survive and grow during the age of globalisation. For example, the Japanese firms are so successful in the global arena because they successfully developed their firms to be a learning organisation, and also realise and expertise in organisational knowledge creation (Nonaka & Takeuchi, 1995).

Senge (1990) highlighted the five disciplines for firms to become a learning organisation, i.e., (1) personal mastery, where every individual needs to show commitment toward the process of learning; (2) mentals models, where every individual needs to unlearn unwanted values and start learning new and applicable values; (3) building shared vision, where every individual in all positions owns the vision and they must has focus and energy for learning; (4) team learning, where every individual needs to share what they have learnt with the team members so that their colleagues could gain new insight knowledge; and (5) systems thinking, where there is an interdependence among people and processes, and every individual needs to work together as a whole system. Principles 1 and 2 occur at the individual learning stage, principles 3 and 4 occur at the group learning stage, and principle 5 occur in the organisational learning stage and interconnected with other four principles. The process of the five disciplines share similarities with the knowledge creation process, where new knowledge is created through a spiral process of knowledge sharing at the individual stage, group stage, and organisation stage (Nonaka & Takeuchi, 1995). Thus, firms need to manage their human resources properly such that they can become a learning organisation.

2.2 HRM practices

HRM is the strategic approach, where firms adopt to manage their employees such that firms can stay competitive in their business environment, promote innovation through coordination of internal and external resources, upgrade firm technological capabilities, and enhance firm performances. The HRM helps firms to utilise internal resources within the organisation and external resources with supply chain partners effectively and efficiently. Thus, the HRM plays a crucial role to develop and enhance knowledge, skill, and abilities of employees to think out of the box and develop innovative ideas to promote innovation, upgrade firm technological capabilities, and maintain sustainable competitive advantages (Lopez-Cabrales, Pérez-Luño, & Cabrera, 2009; Prajogo Daniel & Oke, 2016).

Researchers mainly defined HRM practices based on the context of their studies because understanding practices based on the context are more critical in making senses of what happens in the workplace and provides appropriate solutions for problem-solving (Cooke, 2018). For instance, Zhang et al. (2016) defined HRM practices as (i) top managers hire and evaluate employees based on their abilities, skill, and performance, (ii) firms encourage employees to engage in important decisions and make suggestions for problem-solving, (iii) firms provide specific training to employees to enhance learning and have greater insight into their jobs, and (iv) firms provide flexible strategies and organisational environment to enable employees to develop critical thinking, specific abilities, and skill.

These practices are defined differently from (1) Fey, Björkman, and Pavlovskaya (2011), where HRM practices consist of incentive systems, job security, employee training and career planning, decentralisation, internal promotion, and complaint resolution systems; (2) Glaister et al. (2018), where HRM practices consist of training and development, recruitment and selection, workforce planning, and performance appraisal; (3) Shipton et al. (2005), where HRM practices consist of recruitment and selection, induction, and appraisal and training; (4) Norasingh and Southammavong (2017), where HRM practices consists of recruiting and providing onsite training, owner works closely with communities, providing daily training at work place by experiences villagers, and outsourcing for some new projects that related to crafting product development, and experiences factory manager supervise craftsmen on new product development; and (5) Diaz-Fernandez, Bornay-Barrachina, and Lopez-Cabrales (2017), where HRM practices consist of employee security, training initiative, and compensation policies.

From the concept of knowledge work, firms mainly adopt HRM practices by focusing on recruitment, selection and training, rewards provided to motivate good performance, and development of career tracks to keep employees working with the firms (Newell et al., 2009). Diverse HRM practices are more conducive for promoting innovation when firms adopt these practices as a system such that they can mutually reinforce each other (Delery & Gupta, 2016; Delery & Roumpi, 2017; Laursen & Foss, 2003; Scarbrough, 2003). These encourage employee commitment to the firm as well as update human resource skill and knowledge to prevent obsolescence (Lepak et al., 2006). Across the literature review, firms generate human resources by attracting exceptional talented personnel, developing their capabilities, and rewarding their contributions (Boxall, 1996; Jiang et al., 2012; Jorgensen, Hyland, & Busk Kofoed, 2008; Scarbrough, 2003). Thus, we focus on the three main processes of HRM practices, i.e., (i) recruitment and selection, (ii) training and development, and (iii) retention and compensation. We also identify internal coordination (internal HRM practices) and external coordination (supply chain collaboration) of HRM practices that firms mainly adopted.

2.2.1 Recruitment and selection

Recruitment and selection are the early-stage processes, where firms hire new employees to work inside an organisation. Selection of employees with appropriate skill and attitudes are crucial to enhance team productivities and integrate knowledge from diverse sources (Grandori & Soda, 1995). SMEs mainly do not have systematic recruitment and selection processes. They mainly recruit new employees through connections of existing employees. This process increases higher risks in recruiting disqualified employees to work inside an organisation. However, large firms mainly generate human resource departments to set up specific recruitment and selection procedures. This process helps firms to make sure that newly recruited employees are capable of accomplishing assigned tasks. Glaister et al. (2018) defined risk management, role design, and job analysis as the essential factors to consider for recruitment and selection processes.

2.2.2 Training and development

Even firms could come up with a perfect procedure to recruit and select qualified employees, they still need to provide on-going training and development to current and newly recruited employees. Training and development refer to internal education activities, adopted to enhance knowledge and skill, at the same time also help employees to learn and adapt to the firm's systems, realise their duties, and make them ready for new task assignments. Training and development also help to improve absorptive capabilities of every individual thereby helping them to achieve new knowledge and promote innovation (Chen & Huang, 2009; Chowhan, Pries, & Mann, 2016). Hence, training and development prepare employees for current and future tasks, where training programs also help firms to develop employee skill and knowledge needed for promoting innovation (Jimenez-Jimenez & Sanz-Valle, 2008). Glaister et al. (2018) defined career planning to enhance employees' future values, training to find out future skill needed, and auditing to measure current skill as the essential factors to consider for training and development processes.

2.2.3 Retention and compensation

Firms mainly report problems in retaining qualified employees. Some firms are reluctant to develop their employee capabilities because developing an employee requires high capital investments and time-consuming, and their qualified employees also tend to move to other places (Lam, Chen, & Takeuchi, 2009). Most firms, especially large firms, start adopting specific retention and compensation programs by providing short-term benefits (e.g., rewards in cash, monthly bonus, job-rotation, and other secondment programs) and long-term benefits (e.g., job security, career path development, promotion based on the key performance indicator (KPI) rather than seniority-based, and scholarship to pursue further studies) to keep their qualified employees. Also, some firms create an independent working environment and decentralised decision making with the hope to retain qualified employees (Fey, Björkman, & Pavlovskaya, 2011). Thus, there are various practices to retain qualified employees to be loyal, e.g., proper benefits, adequate compensation, and transparent management, and these practices help firms to access embedded tacit knowledge for upgrading capabilities and promoting innovation.

2.3 Internal HRM practices

Internal HRM practices refer to the firm's activities in utilizing internal resources to create new knowledge, promote innovation, and upgrade capabilities. Subsidiary firms tend to adopt practices, which are inherited from a parent's firm or headquarter. However, this is different for newly established firms, where internal HRM practices are mainly initialised by the top management or experienced managers (Intarakumnerd, 2017). Those practices are mainly used as fundamental activities to create new knowledge for promoting innovation. Foreign firms tend to adopt internal HRM practices and collaborate with supply chain partners simultaneously, but local firms vastly are capable of adopting only internal HRM practices because they have limited financial capital, human resources, external linkages, and experiences (Binh & Linh, 2017). From case studies, firms mainly adopt in-house training (Sobanke et al., 2014), engineer rotation (Li, Wang, & Liu, 2013), R&D personnel development (González, Miles-Touya, & Pazó, 2016), and QCCs (Watanabe, 1991) as their common internal HRM practices. Thus, these internal HRM practices are included in our empirical analysis.

2.3.1 In-house training

In-house training helps to improve and enhance employee capabilities for assigned jobs such that they are capable of promoting innovation. In-house training needs to be conducted regularly for knowledge acquisition of newly recruited employees and knowledge upgrading of current employees such that they are ready for task assignments (Aminullah et al., 2017). In-house training does not only focusing on teaching new things to employees, but also updating their knowledge to follow up on what happened in today's fast-changing societies (Pfeffer, 1994). In-house training helps employees to fully utilise their knowledge with co-workers at individual, group, or organisation levels (Nonaka & Takeuchi, 1995). The literature review showed that investing in in-house training helps firms to enhance human capital at first and organisational performance at last (Delaney & Huselid, 1996; Koch & McGrath, 1996). Sobanke et al. (2014) highlighted the important 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 (2017) defined on-the-job-training, training with customers, learning-by-doing, and field trips as the in-house training. Similarly, Binh and Linh (2017) defined in-house training as new staff recruitment and training through production management. Thus, in-house training consists of four variables, i.e., (1) employees develop training courses without helps from outside, (2) employees develop training materials without helps from outside, (3) employees serve as trainers/lecturers for training courses, and (4) firms have an in-house training facilities/centres.

2.3.2 Engineer rotation

Engineers are the key resources in supporting an organisation to deal with technical tasks, which are mainly incapable by ordinary employees. Firms without engineers are mainly small firms with low technological capabilities, where they do not have adequate resources to acquire engineers, or they do not know the roles of engineers in their organisation 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, an organisation needs to 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, i.e., (1) firms have rotational programs for engineers to rotate various roles in a department, (2) firms have rotational programs for engineers to rotate in various departments, (3) firms have career path programs for engineers to develop leaders of innovative activities, and (4) firms have external secondment programs to give opportunities to engineers to work in other firms. These practices support engineers to integrate their knowledge with an organisational knowledge as well as knowledge from supply chain partners.

2.3.3 R&D personnel development

SMEs mainly do not classify the roles of engineers and R&D personnel, but it does for large firms. R&D personnel is one of the main resources like engineers, but R&D personnel tends to be allocated for promoting innovation (Jeenanunta et al., 2017). Mohan (2017) mentioned that firms provide technical, competency certification and soft skill training programs throughout the year to enhance the competency skill of every employee, and specifically designed for R&D personnel. Thus, R&D personnel capability development can be achieved through various practices, i.e., (1) firms conduct small group activities among R&D personnel, (2) R&D personnel have regular meetings to discuss problems/solutions, and (3) firms develops personnel in charge of R&D.

2.3.4 Quality control circles

QCCs are defined as small group activities, where firms organise for space sharing among their colleagues, and it is also intended to involve everyone in an organisation to co-create new knowledge (Watanabe, 1991). Japanese firms believed that participation, cooperation, and collaboration of every individual through QCCs strengthened the vigour and efficiency of business operations (Watanabe, 1991). QCCs bring benefits in various ways, e.g., 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 organisational performance (Watanabe, 1991). Besides Japan, the QCCs also transferred through the foreign direct investment of Japanese firms to other countries. Local firms, which are suppliers of Japanese firms, are required to adopt QCCs. For instance, Toyota has adopted the QCCs, and when this firm expands its production plants to Thailand, it brought the QCCs. During its business operation, Toyota required local suppliers, e.g., Thai Summit, to adopt QCCs, where these practices are considered as one of the minimum criteria to be Toyota's suppliers. Toyota believed that these practices improved local supplier capabilities to match Toyota standards. QCCs embedded to local suppliers through Toyota's networks, where these networks motivate suppliers to (i) participate and share knowledge openly, (ii) prevent members from free-riding, and (iii) transfer tacit and explicit knowledge effectively and efficiently (Dyer & Nobeoka, 2000). QCCs may consist of (1) firms have systems to disseminate successful experiences of QCCs across the firm, and (2) firms have systems to learn successful experiences of QCC from customers/suppliers.

2.4 External collaboration

Besides internal HRM practices, firms also need to collaborate with external partners, e.g., customers (Bohlmann et al., 2013), suppliers (Lawson, Krause, & Potter, 2015), universities (Bstieler, Hemmert, & Barczak, 2015), consultants, and R&D institutes (Tether & Tajar, 2008), and competitors (Xu, Wu, & Cavusgil, 2013). External collaboration could help firms for knowledge acquisition, knowledge transfer, and knowledge co-creation, which are invisible and embedded outside an organisation (Kafouros & Forsans, 2012; OECD, 2013). 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 is also a moderator between external networks and firm innovation (Ren et al., 2013), (2) family member involvement reduces collaboration with vertical partners (Pellegrini & Lazzarotti, 2019), (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 (Hsieh et al., 2017), (4) collaboration with firms in various countries help firms to acquire varieties of scientific and technological knowledge to improve firm's absorptive capacity (Kafouros & Forsans, 2012), and (5) vertical collaboration helps firms to engage in innovation and optimise the core competency, whereas horizontal collaboration helps firms to identify new opportunities in a new market (Ahn, Kim, & Moon, 2017).

2.4.1 Customer and supplier collaboration

Firms understand how critical collaboration is, 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 organisation (Newell et al., 2009). However, not every firm is capable of exposing their organisation 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 infrastructures, and low managerial skill (Sudhir Kumar & Bala Subrahmanya, 2010). They may not be capable of or ready to collaborate with external partners, specifically with universities, research centres, consultants, and competitors. Most SMEs are only capable of collaborating with suppliers to set up plants and improve current systems and with customers to improve products to match with standard requirements (Hsieh et al., 2017). This is because customers and suppliers are the upstream and downstream partners of the supply chain that help firms to achieve, align, and mobilise resources effectively and efficiently (Bullinger, Auernhammer, & Gomeringer, 2004). Stock, Greis, and Kasarda (2000) stated that supply chain collaboration was highly linked with the cooperation and collaboration of firms with suppliers and customers across extensive enterprises. Therefore, the empirical study of this dissertation considers only customers and suppliers as the key external partners.

Collaboration with customers and suppliers are mainly studied together, e.g., (1) customers are important for product innovation, whereas suppliers are important for process innovation (Reichstein, Salter, & Gann, 2008), (2) supplier collaboration helps firms to achieve radical innovation, whereas customer collaboration help firm to achieve incremental innovation (Yunus, 2018), (3) collaboration with one partner (e.g., customers) increase the likelihood of collaboration with a different partner (e.g., suppliers) (Roper, Du, & Love, 2008). Researchers also have studied separately for customer and supplier collaboration, e.g., (1) collaboration with customer enable firms to refine R&D direction and enhance internal competencies by assisting in product design, technology, project management, and prototype assessment (Menguc, Auh, & Yannopoulos, 2014; Tsai, 2009), (2) relationships between supplier collaboration and innovation novelty might depend on stages of supplier involvement, e.g., predesign or commercialisation stage (Song & Thieme, 2009) and innovativeness capabilities of suppliers (Kibbeling, Van Der Bij, & Van Weele, 2013), (3) supplier collaboration has strong relationships with radical product innovation rather than incremental (Amara & Landry, 2005; Freel & Harrison, 2006; Harhoff, Mueller, & Van Reenen, 2014).

Researchers highlight the importance of supply chain collaboration but studying supply chain collaboration without considering internal HRM practices may lead to bias conclusions. For example, if firms have adequate internal capabilities, they may not collaborate with suppliers, and they just need to collaborate with customers to acquire new knowledge for product improvement. Therefore, studying the supply chain collaboration in combination with the internal HRM practices helps us to get new insight knowledge for promoting innovation in formal and non-formal R&D firms. In this study, customer and supplier collaboration consists of various practices, i.e., (1) the main customer/supplier dispatches personnel to the firm, (2) firms provide training to the main customer/supplier, (3) firms receive training from the main customer/supplier, (4) firms design a new product or service with the main customer/supplier, (5) firms' engineers obtain new technologies and knowledge through training at/learning from customers/supplier, (6) firms ask advice from/cooperate with foreign-owned (MNC/JV) customers/suppliers, and (7) firms' engineers communicate directly with engineers of customers/suppliers.

2.4.2 Knowledge transfer and knowledge stickiness

Knowledge is transferred back and forth between the headquarters and its overseas affiliates, or among the partners in the supply chain networks. For example, the expatriates are the agents of knowledge transfer from the headquarters to its subsidiaries, and the same expatriates are also the agents to learn new knowledge from the overseas affiliates and share experiences and knowledge with the headquarters (Tsang, 1999). Even knowledge is transferred back and forth, it is not equally distributed. The local firms, especially SMEs, mainly have limited capabilities in human resources, financial capital, and organisational infrastructures. They mainly have limited absorptive capacity. Kafouros et al. (2008) stated that firms may not absorb adequate knowledge transfer from foreign firms or related partners for technology upgrading and innovation if their absorptive capacity is below the threshold for knowledge acquisition.

Also, knowledge tends to be sticky and hard to transfer from one firm to another, where knowledge stickiness is defined as difficulties that firms encounter during knowledge transferring processes (Szulanski, 1995). Knowledge stickiness is a barrier for knowledge transfer, where it may be very costly, time-consuming, and in some cases may lead to unsuccessful transferring of knowledge (Szulanski, 1996). Choo (1996) stated that knowledge stickiness occurs when the information is still an individual tacit knowledge, or when the users (subsidiaries) are not familiar with those kinds of tacit knowledge. Li and Hsieh (2009) suggested that firms could transfer their knowledge successfully with their subsidiaries or partners when they have specific processes of knowledge transfer implementation and internalisation so that they can achieve more satisfaction in knowledge transfer for technology upgrading and innovation.

2.5 Main mentors for promoting innovation

Firms realise how critical internal HRM practices and collaboration with supply chain partners are, but these practices do not occur by itself. They need to be initialised and adopted by top management – the key person, e.g., chairperson, chief executive officer, managing director, president – who initialised strategies and policies that influenced every individual in the organisation, and s/he held the whole responsibilities for the success or failure of business operations. The top management also needs to align HRM strategies with organisational structures to achieve the firm goals. The top management should have industrial knowledge and work experiences in promoting innovation such that s/he can free tacit knowledge from every individual and make it widely available as organisational explicit knowledge (Newell et al., 2009). Knowledge, unlike money, is not valuable by itself, but it is valuable when it is applied to deal with a specific task (McDermott, 1999). Boland and Tenkasi (1995) mentioned that "managing knowledge is not only converting, capturing, and transferring different forms of knowledge, but also enabling context that connects different social groups and interests to accomplish a specific task". Therefore, top management plays an important role to enable context that fosters and facilitates knowledge for upgrading firm capabilities and promoting innovation (Newell et al., 2009).

There are various management styles, e.g., top-down (Conway & Monks, 2011), bottom-up (Conway & Monks, 2011; Kozlowski & Klein, 2000), and middle-up-down (Nonaka et al., 2008), where firm in emerging economies such as Thailand and other countries in Southeast Asia mainly adopt top-down management, where the top management mainly initialises ideas to create new knowledge for promoting innovation. This is different from bottom-up and middle-up-down management, where the role of every individual is critical for knowledge creation and co-creation. This does not mean that the top management of bottom-up and middle-up-down management styles are not important, but s/he decentralises tasks for everyone because s/he believes knowledge is embedded in every individual in an organisation (Watanabe, 1991). Watanabe (1991) mentioned that most Japanese firms adopt QCCs and other small group activities for knowledge co-creation because they believe that shop-floor employees know their jobs better than anybody else. Therefore, the top management needs to adopt management practices, which are suitable for the context of their business operation.

Researchers highlight how important top management is, e.g., top management openness is an antecedent to absorb capacity for promoting innovation (Slavec Gomezel & Rangus, 2019), top management defines direction for an organisation and enable the culture to execute activities to achieve firm's vision (Bingham & Spradlin, 2011), low-tech firms with top management experienced as the boards of high-tech firms tends to be more capable to promote innovation (Reguera-Alvarado & Bravo, 2018), top management with visionary leadership can motivate employees in the workplace and reduce their anxieties (Chen & Chen, 2013). Researchers mainly focus on how critical top management is in promoting innovation, but is s/he working alone, or getting knowledge from other key persons? Who is co-working with the top management? Does the main mentors among formal and non-formal R&D firms are differences? This leads us to consider employees from various positions, i.e., top management, heads of R&D departments, engineers in R&D departments, managers of cross-functional teams, employees of cross-functional teams, engineers in non-formal R&D departments, production line leaders, factory workers, and office workers, as the potential main mentors for promoting product innovation in our empirical study.

2.6 Firm technological capabilities

Firms have different technological capabilities, so it is important to find the best fit of HRM practices for technology upgrading and innovation based on their capabilities. Arnold et al. (2000) defined four stages 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 stage of technology use and operation to the complex stage of R&D. Then Tsuji et al. (2018) and Intarakumnerd (2017) grouped these capabilities as formal and non-formal R&D firms. Formal R&D firms are organisations with systematic and organised activities, e.g., have engaged in systematic innovation, have established an R&D department, or have allocated budgets for the purpose of R&D, conducted to promote innovation and improve performance (OECD., 2015). Large firms tend to have stronger capabilities to invest in formal R&D (Intarakumnerd, Chairatana, & Tangchitpiboon, 2002; Petsas & Giannikos, 2005) and possess innovative advantages over smaller firms in terms of heterogeneous R&D activities (Choi & Lee, 2017).

Whereas, non-formal R&D is a process of collecting, processing, and applying information for problem-solving (Kleinknecht, 1987). Similarly, Tsuji et al. (2017b) defined non-formal R&D as firms without systematic or organised activities for conducting R&D to promote innovation. Non-formal practices, e.g., designs, utilisation of advanced machinery, and training, are critical for promoting innovation, especially in low and medium technological industries (Santamaría, Nieto, & Barge-Gil, 2009). Tsuji et al. (2018) stated that formal R&D firms promote product innovation by cross-functional teams of production, engineering, marketing, and IT usage, whereas non-formal R&D firms promote product innovation by HRM programs for employees, group awards for suggestions, and ISO9000. Therefore, formal and non-formal R&D are the key indicators to define firm technological capabilities. From this study, formal and non-formal R&D firms are defined as firms that have and have not allocated some portion of their sale budgets for the R&D purpose, respectively.

2.7 Innovation

Firms adopt internal HRM practices and collaborate with supply chain partners to acquire new knowledge and use it to integrate with existing knowledge. Co-creation of knowledge is intended for promoting innovation as well as enhancing firm performances such that firms can maintain their survival and growth during today's fast-changing and hyper-competitive of the business environment.

Innovation refers to changes in products/services of a firm in a way that the firm produces them, changes in business models, improves management techniques, and modifies organisational structures (Schumpeter, 1934). Then it is redefined as the process of exploration (i.e., inventing new knowledge) and exploitation (i.e., reusing existing knowledge in new contexts) (Newell et al., 2009), or processes of development and implementation of existing ideas in a new context or new ideas on an existing context (Van de Ven, 1986). Innovation is highly context-oriented, so what works in one context may not be applicable in another context (Swan, Newell, & Robertson, 1999). It highly depends on firm sizes (Reichstein & Salter, 2006; Saha, 2014), financial capital (Martinez-Ros, 1999; Zhang & Yin, 2012), human resources (Capitanio, Coppola, & Pascucci, 2010; Zhang & Yin, 2012), strategies and manufacturing capabilities (Ribau, Moreira, & Raposo, 2019), absorptive capacity (Chandrashekar & Mungila Hillemane, 2018; Lew & Liu, 2016), and collaboration levels with supply chain partners (Arranz & Fdez. de Arroyabe, 2008; Belderbos, Carree, & Lokshin, 2004; Maietta, 2015; Miotti & Sachwald, 2003; Yunus, 2018). Thus, innovative firms utilise existing knowledge/technologies and explore entirely new knowledge/technologies, so firms need to learn how to unlearn outdated practices and learn how to relearn new practices such that they can improve firm competency and drive innovation (Bingham & Spradlin, 2011).

Innovation entails three main phases (i) idea generation, which mainly focus on collaboration within units, across units, and outside parties, (ii) idea conversion, which mainly focuses on screening, and funding of new ideas, developing ideas into viable products, services, or businesses, and (iii) idea diffusion, which is the spread of developed ideas within and outside the organisation (Hansen & Birkinshaw, 2007). These three phases are interrelated and interdependent with one another, so firms cannot just focus on one of them, e.g., idea generation, idea conversion, or idea diffusion, they need to consider these three phases as a chain. Firms should innovate by looking at the entire forest rather than focusing on a single tree, and this helps firms to achieve global rather than local optimum innovation.

2.7.1 Close and open innovation

Promoting innovation is also highly related to closeness and openness of the firms, where choices for open and closed innovation depend on internal knowledge availability (Hsieh et al., 2017). Closed innovation is a process in which products/services invention take place within an organisation without collaborating with outside partners, so innovators share risk alone for promoting innovation; however, open innovation is a process in which products/services invention occur through cooperation and collaboration of resources within an organisation with resources from supply chain partners. Hence, open innovation helps to balance the innovation portfolio and share risks with supply chain partners (Bingham & Spradlin, 2011). This is clear that firms with open innovation tend to have better knowledge sharing environments, and this helps firms to achieve more innovation (Ferraris, Santoro, & Bresciani, 2017). The more firms adopting knowledge sharing, the more firm diverse collaboration networks, and these generate new knowledge and promote innovation (Beck & Schenker-Wicki, 2014; Berchtold, Pircher, & Stadler, 2010).

2.7.2 Radical and incremental innovation

Innovation sounds simple and easy to talk. We may hear innovation quite often; however, innovation is actually unknowable in advance, and not easy to achieve innovation in practices (Dougherty, 2007). Open innovation mainly helps firms to achieve innovation whether it is radical innovation – an achievement of a technological breakthrough in product or process, e.g., producing a new product or introducing a new process – or incremental innovation – an improvement of products or processes, e.g., process improvement and innovation in packaging (Mangematin & Mandran, 2001; Tsuji et al., 2017b). Jugend et al. (2018) mentioned that radical and incremental product innovation requires different management practices, i.e., incremental product innovation may not require greater integration efforts, where radical product innovation may require intense involvement of technical teams and flexibilities. Hsieh et al. (2017) suggested that firms could achieve radical innovation through collaborating with domestic competitors and foreign customers, and incremental innovation through strengthening collaboration with foreign consultants and private research centres.

2.7.3 Product innovation

There are various types of innovation, e.g., product, process, packaging, organisational, position, marketing, and commercial (Mangematin & Mandran, 2001). These innovations are investigated from case studies; however, only product innovation is investigated in the empirical study because manufacturing firms mainly embedded their innovative ideas in products. Product innovation is a process of improving existing products or introducing a completely new product (Rogers, 1998; Saha, 2014). Aminullah et al. (2017) mentioned that SMEs tend to achieve product innovation at a very basic phase, e.g., dispensing from their owned recipe and improving existing products, through trial-and-error, whereas vertical integrated firms and global oriented large firms tend to achieve up to the highest phase of product innovation, e.g., development a new product based on existing technology and new technology, through setting their owned R&D and/or collaborate with supply chain partners, universities, and research centre.

Mangematin and Mandran (2001) defined three features of product innovation, i.e., (i) improving existing products; (ii) producing products which are new to a firm, but already existed in a market; and (iii) producing products which are new to a market. Similarly, Ogawa et al. (2018); Tsuji et al. (2017a); Tsuji et al. (2016); Tsuji, Minetaki, and Akematsu (2011); Tsuji et al. (2018); Ueki and Tsuji (2019) categorised product innovation, as (i) redesigning packaging or significantly changing appearance design, (ii) significantly improving existing products, (iii) producing new products based on existing technologies, and (iv) producing new products based on new technologies. These classifications are adopted in the empirical study because they show various types of product innovation in different levels of difficulties.

2.8 Thai manufacturing context

Thailand is the second-largest economy in Southeast Asia behind Indonesia, with the economic growth of 2.4% and the gross domestic product of USD 520 billion in 2019, and this represents 0.43% of the world economy (TradingEconomics, 2019). Thailand is an export-oriented country, where the manufacturing industry became one of the main industries for economic growth, accounting for 34% of GDP along with 44% from services, 13% from agriculture, and 9% from other related industries (TradingEconomics, 2019). For the manufacturing industry, electronics (14%), vehicles (13%), machinery and equipment (7.5%), and food stuffs (7.5%) are among the most export products, where the major export partners are China (12%), the United States (10%), Japan (10%), and the European Union (9.5%) (TradingEconomics, 2019).

To develop a sustainable economy, the Thai government started focusing on science, technology, and innovation (STI). In 2016, Thailand's STI budget was divided into four categories, R&D, Scientific and Technological Services, Scientific and Technological Education and Training, and Innovation; and these accounted for 25%, 19%, 55%, and 1% of the budget, respectively (STI, 2016). The Thai government also encouraged cooperation between the public and private sectors. In 2014, the gross expenditure on R&D was equivalent to 0.48% of Thailand's total GDP (54% private sector and 46% public sector). Thailand's public sector has 37,525 researchers (27% Ph.D., 64% Master, and 6% Bachelor researchers), while its private sector has 28,440 researchers (2% Ph.D., 15% Master, and 83% Bachelor researchers) (STI, 2016).

Lately, the Thai government starts to promote Industry 4.0, which is an integration of smart technologies, e.g., internet of things, robotics, automation, cloud computing, and cyber-physical product systems, to increase automation capabilities insight the plants, improve employee productivities, enhance data sharing and data analysis, and achieve high efficiency. These are less difficult in planning, but truly hard to achieve in reality because innovation systems among Thai manufacturing firms are still poor and fragmented, where local firms, especially SMEs, still have limited technological capabilities (Intarakumnerd & Virasa, 2002). They still do not have innovation and continuous improvement culture, where sources of knowledge for promoting innovation are mainly achieved through knowledge transfer from foreign direct investors. Firms especially SMEs do not allocate budget for R&D, and the Thai universities also have limited research performance in terms of international journal publications (Intarakumnerd, Chairatana, & Tangchitpiboon, 2002). The linkage among universities, research centres, and industries are also weak, so these are the flaws in Thai innovation systems (Intarakumnerd, Chairatana, & Tangchitpiboon, 2002).

In terms of HRM practices, Thai firms mainly adopted trial-and-error, adopted simple training, and provided employees on-the-job training before 1960. During the 1960s, firms in Thailand started adopting HRM, but without precise procedures in recruitment and selection, training and development, and retention and compensation. During the 1980s, firms started introducing various HRM practices, e.g., management development program, QCCs, quality control and assurance, 5S. During the late 1990s, Thai firms started to adopt more advanced practices, e.g., performance management, career path development programs, open innovation, talent management, and lean manufacturing. They also started to improve employee knowledge and skill with the purpose of developing their organisation to be a learning organisation. As a result, these HRM practices help to improve local firms' competitiveness during today's fast-changing and hyper-competitive business environment.

CHAPTER 3
RESEARCH METHODOLOGY

Overview: This chapter summarises the mixed methodology, which is an adoption of qualitative analysis and qualitative comparative analysis. First, the qualitative analysis is adopted to analyse three cases, selected from the Thai manufacturing industry. Details of case studies are presented in Chapter 4. Then the qualitative comparative analysis is adopted to empirically analyse data, collected from the Thai manufacturing industry. Details of the empirical studies are presented in Chapter 5.

3.1 Research design

Sources of knowledge for technology upgrading and innovation tend to vary from one context to another, where the best practices in one context may cause problems in another context if the top management just fully adopted those practices without understanding contexts of business operation (Newell et al., 2009). Hence, this is worth finding the best fits of HRM practices, which are suitable for the Thai manufacturing context. We believe that the role of skill and tacit knowledge differ across firms and countries in upgrading firm technological capabilities and promoting innovation. The **MRQ** and **SRQs**, as presented in Chapter 1, are responded by using the mixed methodology, which consists of qualitative analysis (Yin, 2017) and qualitative comparative analysis (Ragin, 2008). The qualitative analysis is adopted to answer **SRQ1**: What types of HRM practices are needed to upgrade firm technological capabilities? and **SRQ2**: How and when firms adopt HRM practices to upgrade their technological capabilities, e.g., from non-formal to formal R&D? Then we conduct the qualitative comparative analysis to answer **SRQ3**: How firms combine internal and external HRM practices to promote innovation when they base in different stages of technological capabilities? and **SRQ4**: Who are the main mentors to manage human resources for innovative activities across different stages of firm technological capabilities? Details of the research framework are presented in Figure 3.1. Then we will recap our findings to answer the **MRQ**: What types of HRM practices can be sources for upgrading firm technological capabilities in the Thai manufacturing context? how and why?

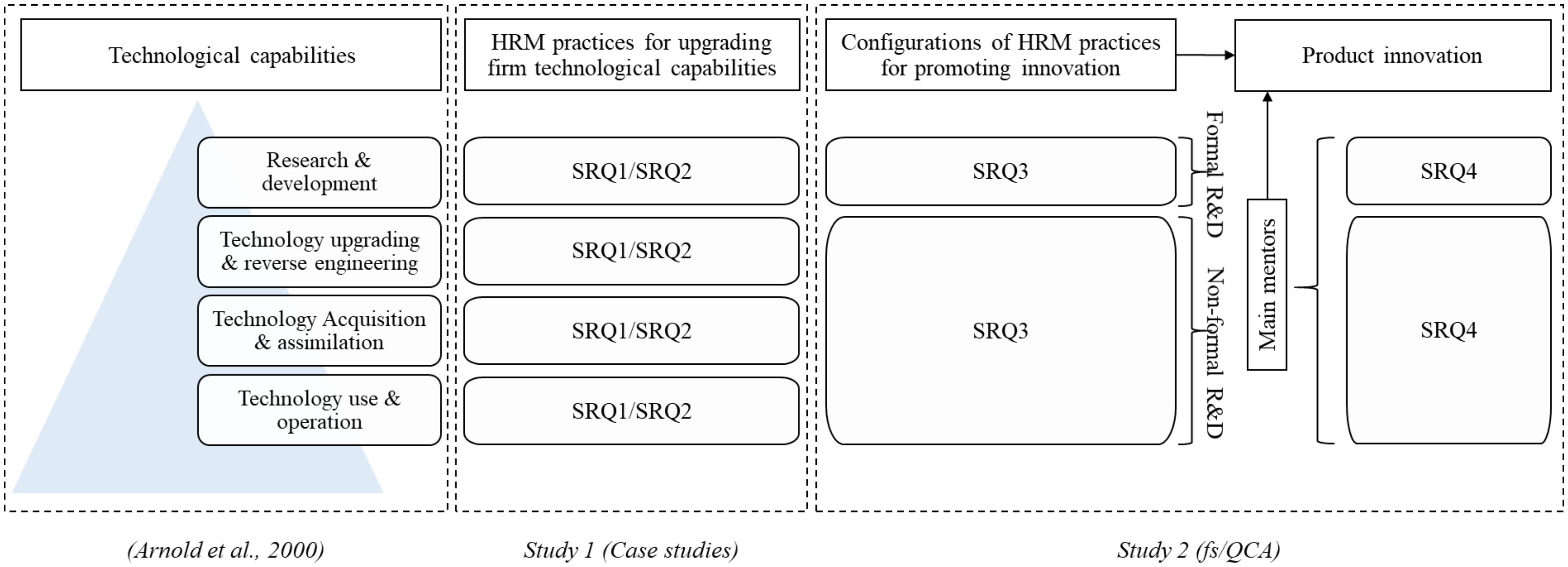

Figure 3.1: Research framework (*Source*: Author)

3.2 Qualitative analysis (Case study)

The qualitative analysis is intended to learn, explore, and extend our knowledge on HRM practices for upgrading firm technological capabilities. Yin (2017) has presented six steps for case studies analysis, i.e., planning, designing, preparing, collecting, analyzing, and sharing. In this study, as presented in Figure 3.2, we first conduct an intensive literature review on knowledge-based view, internal HRM practices, supply chain collaboration, technological capabilities, and innovation from the local and international context. We intend to explore the **MRQ**: What types of HRM practices can be sources for upgrading firm technological capabilities in the Thai manufacturing context? how and why? From the **MRQ**, we designed a set of semi-structured questions for an in-depth interview, by adopting the framework from the Economic Research for ASEAN and East Asia (ERIA). Then the semi-structured research questions are commented on and reviewed by an academic professor for questionnaire validation. Details of the semi-structured questions for in-depth interview are presented in Appendix A.

A multiple case analysis is implemented for qualitative analysis. This method can provide a profound understanding and hidden information for cross-case comparisons (Eisenhardt, 1989). Three manufacturing firms in Thailand, i.e., Global Green Chemicals Public Company Limited (GGC), Thai Oil Public Company Limited (Thai Oil), Siam Cement Group Chemicals Company Limited (SCG Chemical), are purposely selected for in-depth case studies. These three firms are selected because they are 100% locally-owned, who experience successful transitions in upgrading their technological capabilities from non-formal to formal R&D. These three firms could be considered as good cases for technology upgrading in the Thai manufacturing context.

Each firm is contacted to make an appointment for in-depth case studies. First, we interviewed the CEO from the GGC on 05 January 2017. Then, we had the second interview on 26 January 2017 with a managerial manager from the SCG Chemical. Finally, we had the third interview on 15 February 2017 with three people, a managerial manager and two heads of departments, from the Thai Oil. The interview took place at the offices of each company, and it took around forty-five minutes to one hour and a half. During the interview, we took notes and asked permission from the interviewee to make voice records. We promised them to keep confidential information that leads to identifying respondents and information that may cause firms at risk.

The notes and audio tape are summarised with the support from the academic professor. Information, which is not available or incomplete during the interview, is checked to confirm from the annual and quarterly reports of each firm. The key milestones of each firm are pinpointed to investigate types of internal and external coordination that each firm implemented for upgrading their capabilities, and the results are analysed via cross-case comparisons. Then we conclude HRM practices needed to upgrade firm technological capabilities.

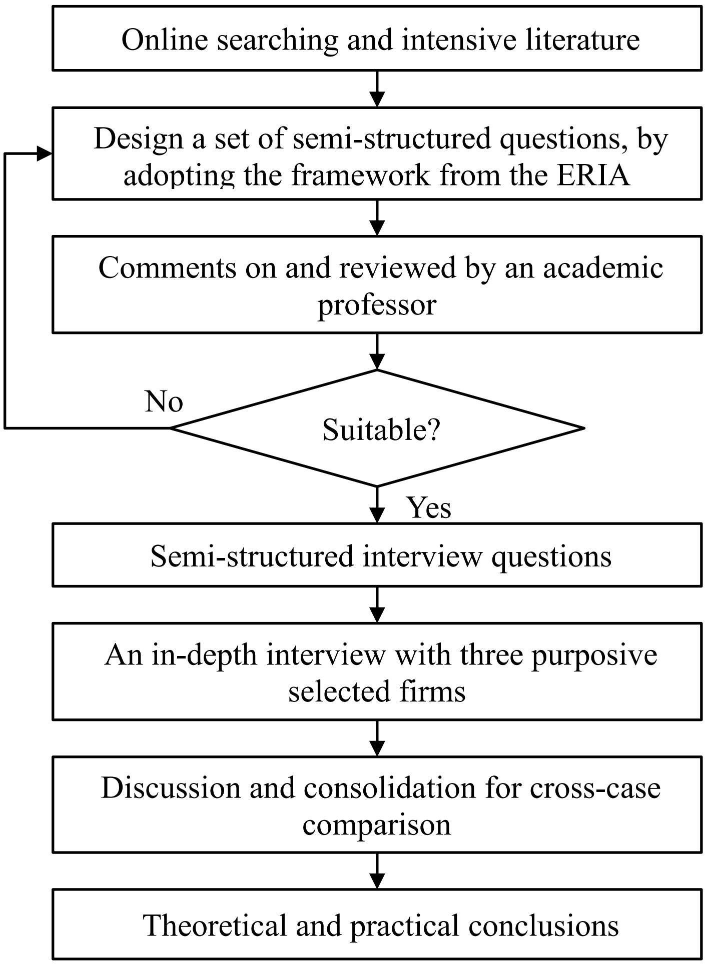

Figure 3.2: Processes of conducting qualitative analysis

3.3 Qualitative comparative method (fs/QCA)

The empirical study is motivated by in-depth case studies with Thai manufacturing firms. This study intends to answer the **SRQ3**: How firms combine internal and external HRM practices to promote innovation when they base in different stages of technological capabilities?, and **SRQ4**: Who are the main mentors to manage human resources for innovative activities across different stages of firm technological capabilities? The process of the empirical study is presented in Figure 3.3.

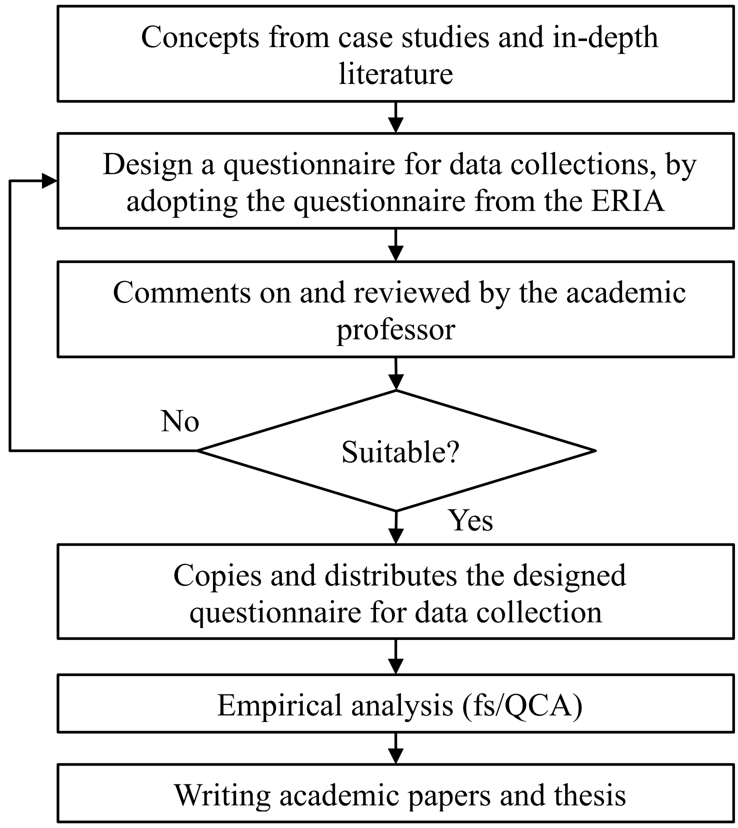

Figure 3.3: Processes of conducting qualitative comparative analysis

3.3.1 Sample and data collections

Combining knowledge from case studies and intensive literature review, the questionnaire, i.e., (1) profile of the establishment to provide basic information of firms, (2) achievement for upgrading product innovation to identify different types of products innovation, (3) internal HRM practices, which consist of in-house training, engineer rotation, R&D personnel development, and QCCs, (4) supply chain collaboration to highlight on customer and supplier collaboration, and (5) main mentors for promoting innovation, was designed for data collections, as presented in Appendix B. The questionnaire was designed, by adopting the framework of questionnaire from the ERIA. Then designed questionnaire was commented on and reviewed by an academic professor for questionnaire's validation.

The questionnaire was distributed to firms, located in the Bangkok metropolitan area, Thailand. This area is a centre of economics, and it is the main gateway for national and international trade. This area has major industrial zones and factories for data collection

(Maurice, 2018). A list of 1,200 firms was sampling on December 3rd, 2016 from firms that registered their business in the database of the Department of Industrial Works, Ministry of Industry, Thailand (MOI, 2015). Each questionnaire was distributed to respondents, which are expected to be the key person in managerial positions, e.g., presidents, chief executive officers, directors, managers, heads of departments, and group leaders. The questionnaires were distributed and collected from December 2016 to February 2017. There were three means for data collection, i.e., email, post-office, and walk-in, and the return rate for each mean is 2.08%, 2.67%, and 100%, respectively. In total, there are 209 respondents, which is equivalent to 17.42%. Details on data collection are presented in Table 3.1.

Table 3.1: Data collection

Distribution	Email	Post	Walk-in	Total number of respondents
Return Rate	25	32	157	209
Return Rate (%)	2.1%	2.7%	100.0%	17.4%

3.3.2 Data cleaning

There are three steps for data cleaning, as presented in Table 3.2. First, respondents who do not respond the R&D expenditures are excluded from this analysis because we cannot categorise whether they are belonging to formal or non-formal R&D firms. Second, respondents were asked whether firms have product innovation in the last two years. If their response is 'Yes', they are required to answer each type of product innovation; otherwise, they go to the next questions without responding to each type of product innovation. Third, data from respondents is analysed by using fuzzy-set qualitative comparative analysis (fs/QCA) (Ragin & Davey, 2016). This method cannot deal with missing data, so respondents that have missing values on causal conditions and outcomes are removed. From steps 1, 2, and 3, we removed 9, 68, and 45 respondents from each step, respectively. Therefore, only 87 respondents were included for further empirical fs/QCA.

Table 3.2: Data cleaning

Data-cleaning process	Step 1	Step 2	Step 3
Total	209	200	132
Invalid (Removed)	9	68	45
Valid	200	132	87

3.3.3 fs/QCA

Qualitative comparative analysis (QCA) is defined as a set-theoretical method operated by using Boolean algebra to deal with causal complexity in binary variables (Ragin, 1987). Then Ragin (2008) introduced fuzzy-set QCA (fs/QCA) to deal with continuous and interval variables. Researchers, who adopted Ragin (2008) methods, believed that the fs/QCA technique combines strengths of qualitative and quantitative approaches, and it is also the bridge between case-oriented and variables-oriented research (Ragin, 2008). The fs/QCA does not analyse effects or relationships of causal conditions to explain an outcome but to explain how causal conditions combine in the complexity to generate an outcome (Tóth et al., 2015). Simply Ragin (2008) stated on page 183 that "The goal of fs/QCA is to derive a logically simplified statement describing the different combinations of causal conditions linked to an outcome".

There are three main benefits of the fs/QCA, compared to conventional methods. First, fs/QCA can deal with equifinality, where this method is capable of explaining various configurations that lead to a single outcome (Fiss, 2007). Second, fs/QCA can deal with asymmetry, which means that a presence or an absence of a causal condition leads to an outcome requiring different explanations (Fiss, 2007). Third, fs/QCA can be analysed with a small set of data (Ragin & Rihoux, 2004). Therefore, the fs/QCA is adopted to analyse configurations that lead 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 fs/QCA overcomes limitation of the conventional methods, e.g., regression analysis and correlation, as follows. First, symmetric or asymmetric correlations among causal conditions and outcomes can be conducted by fs/QCA (Ragin, 2008). Second, Fiss (2011) stated that "fs/QCA do not disaggregate cases into independent and then analyse separately, but instead treat configurations as different types of cases". Third, Fiss (2011) also added that "the basic intuition underlying fs/QCA is that cases are best understood as configurations of attributes resembling overall types and that a comparison across cases can allow researchers to strip away attributes that are unrelated to the outcome in question."

3.3.3.1 Logical operation and notations of fs/QCA

The fs/QCA is computed by using Boolean algebra to reformulate data matrix to be a truth table, and reduced the truth table by using simple logical operation (Ragin, 2008). There are three main logical operations, presented by Ragin (2008). First, the logical NOT (~) is the membership in the sets subtract from 1. Second, the logical AND (*) refers intersection or combination of two or more sets, where in formula logical AND is the minimum of membership scores of each case in the set. Third, the logical OR (+) refers to union of two or more sets, where in formulae logical OR is the maximum of membership scores of each case in the set. Details of logical operators using in fs/QCA are presented in the Table 3.3.

Table 3.3: Logical operators using in fs/QCA

Notation	Logical operator	Description	Equation
~	NOT	Negation of the original value	~X = 1-X
*	AND	Set intersection – calculated as the minimum value of two (or more) sets	X*Y = min (X, Y)
+	OR	Set union – calculated as the maximum of two (or more) sets	X+Y = max (X, Y)

There are additional three notations, which are used to simplify and summarise the results of the fs/QCA. First, bold bullet point (●) indicates a presence of the causal condition. Second, circle bullet point (○) indicates an absence of the causal condition. Third, blank space ( ) indicates a presence or an absence of the causal condition.

3.3.3.2 Causal conditions and outcomes

There are five main parts of the questionnaire, which are used for this empirical study, where details are presented in Appendix B. The causal conditions, i.e., internal HRM practices, supply chain collaboration, and main mentors, are achieved from Parts 3, 4, and 5, respectively, and measured by using the dichotomous scale, where 0 = ‘No’ and 1 = ‘Yes’. Whereas the outcome, i.e., product innovation, is achieved from Part 2 and measured by the 3-point Likert scale (Tsuji et al., 2018; Ueki & Tsuji, 2019), where 0 = ‘Not Tried Yet’, 1 = ‘Tried’, and 2 = ‘Achieved’. Details on the causal conditions and outcomes are presented in Table 3.4 and Table 3.5. The Cronbach’s alpha coefficient of the causal conditions for formal and non-formal R&D firms are presented in the last two columns to test the reliability of the constructed variables. Cronbach’s alpha coefficient ranged from 0.727 to 0.920, so each constructed variable exceeded the threshold value of 0.7 (Nunnally, 1978). They can be grouped for further empirical fs/QCA.

Table 3.4: Cronbach's alpha of causal conditions and outcomes

Causal conditions (Internal HRM practices, supply chain collaboration, and main mentors) and outcomes (product innovation)			Formal R&D (38)	Non-formal R&D (49)
Internal HRM practices	In-house training (*it*)	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 facilities/centres.	0.808	0.781
	Engineer rotation (*er*)	Firms have rotational programs for engineers to rotate various roles in a department. Firms have rotational programs for engineers to rotate in 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*)	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	0.920
	Quality control circles (*qcc*)	Firms have systems to disseminate successful experiences of QCCs across the firm. Firms have systems to learn successful experiences of QCC from customers/suppliers.	0.782	0.777
Supply chain collaboration	Customer collaboration (*cc*)	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 at/learning from customers. Firms ask advice from/cooperate with foreign-owned (MNC/JV) customers. Firms' engineers communicate directly with engineers of customers.	0.759	0.807

Table 3.5: Cronbach's alpha of causal conditions and outcomes (Con't)

Causal conditions (Internal HRM practices, supply chain collaboration, and main mentors) and outcomes (product innovation)			Formal R&D (38)	Non-formal R&D (49)
Supply chain collaboration	Supplier collaboration (*sc*)	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 at/learning from suppliers. Firms ask for advice from/cooperate with foreign-owned (MNC/JV) suppliers. Firms' engineers communicate directly with engineers of suppliers.	0.727	0.783
Main mentors		Top Management (*tm*) Heads of R&D departments (*hrdd*) Engineers in R&D departments (*erdd*) Managers of cross-functional teams (*mct*) Employees of cross-functional teams (*ect*) Engineers in non-formal R&D departments (*enrdd*) Production line leaders (*pll*) Factory workers (*fw*) Office workers (*ow*)		
Product innovation (*pdi*)		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*).		

3.3.3.3 Data preparation and variables calibrations

The causal conditions and outcomes need to be normalised to fuzzy variables, which range between 0 and 1 (Ragin, 2008). There are three steps, which are used to transform variables to be fuzzy variables as presented in Figure 3.4.

No normalisation needs for the main mentor variables because they were collected by using the dichotomous scale and they were not grouped. There are three steps to normalise internal HRM practices, supply chain collaboration, and product innovation. First, every variable must be ranged from 0 to 1, so no normalisation 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 normalised between 0 and 1. If respondents answer 0, 1, or 2, the values need to be normalised as 0, 0.5, or 1, respectively. Second, there are sub-variables in in-house training, engineer rotation, R&D personnel development, QCCs, customer collaboration, and supplier collaboration, so 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 ranges between 0 and 1. Then data from step 1 and step 2 are transformed into set membership scores ranging between 0 (full non-membership) and 1 (full membership) (Ragin, 2008). 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 of formal and non-formal R&D firms are presented in Table 3.6 and Table 3.7, respectively. Then membership scores of the causal conditions and outcomes are calibrated by using fs/QCA 3.0.

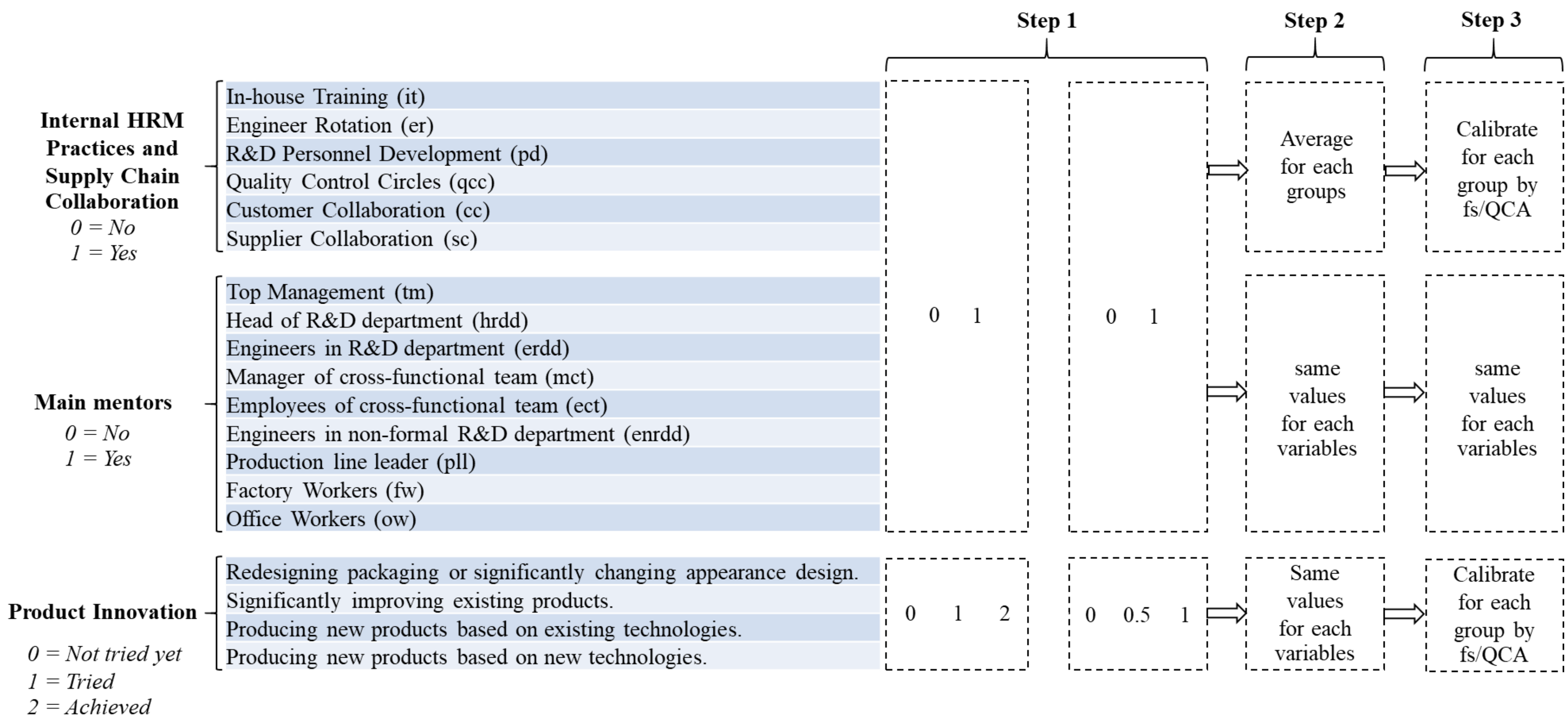

Figure 3.4: Data preparation and variables calibration

Table 3.6: Causal condition 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 (5% percentile)	0.000	0.000	0.000	0.000	0.000	0.136	0.475	0.000	0.500	0.000
Crossover point (50% 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 (95% percentile)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 3.7: Causal condition 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 (5% percentile)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Crossover point (50% 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 (95% percentile)	1.000	1.000	1.000	1.000	0.929	0.857	1.000	1.000	1.000	1.000

3.3.3.4 Necessity analysis

Necessity analysis is conducted to identify sufficient and necessity conditions. If the consistency values of a causal condition exceeds the threshold values of 1.0, that causal condition is considered as a necessary condition as shown in Figure 3.5, where an outcome is a subset of a causal condition; otherwise, it is considered as a sufficient condition as shown in Figure 3.6, where a causal condition is a subset of an outcome (Ragin, 2008). The high and low levels of each causal condition (internal HRM practices, supply chain collaboration, and main mentors) were tested in relation to the high and low levels of outcomes (types of product innovation).

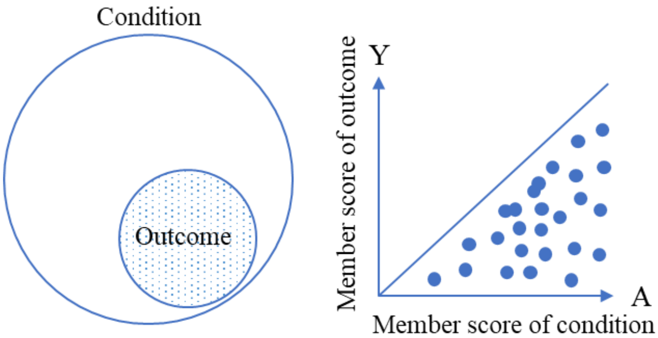

Figure 3.5: Necessary conditions

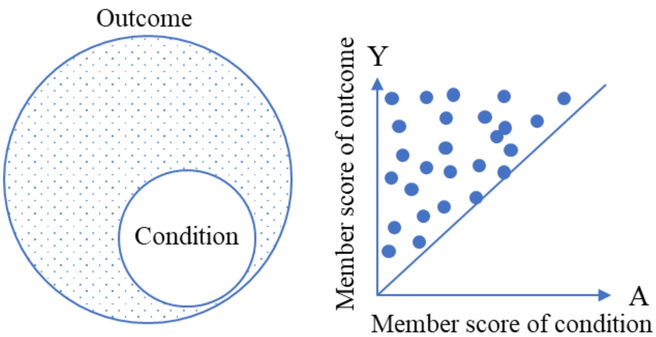

Figure 3.6: Sufficient conditions

The results from necessity analysis indicate that none of the causal conditions of formal and non-formal R&D firms exceeded 1.0 as illustrated in Table 3.8 and Table 3.9 for HRM practices and Table 3.10 and Table 3.11 for main mentors to promote innovation, respectively. This means that there are no necessity conditions for 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, supply chain collaboration, and main mentors.

Table 3.8: Necessity analysis of HRM practices in formal R&D firms

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

Table 3.9: Necessity analysis of HRM practices in non-formal R&D firms

HRM practices		*it*	*~ it*	*er*	*~ er*	*pt*	*~ pt*	*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

Table 3.10: Necessity analysis of main mentors in formal R&D firms

Main mentors		*tm*	*~ tm*	*hrdd*	*~ hrdd*	*erdd*	*~ erdd*	*mct*	*~ mct*	*ect*	*~ ect*	*enrd*	*~ enrd*	*pll*	*~ pll*	*fw*	*~ fw*	*ow*	*~ ow*
pdi1	Consistency	0.698	0.302	0.477	0.523	0.175	0.825	0.091	0.909	0.042	0.958	0.084	0.916	0.095	0.905	0.131	0.869	0.042	0.958
	Coverage	0.563	0.680	0.632	0.562	0.564	0.600	0.342	0.641	0.950	0.584	0.950	0.574	0.307	0.658	0.590	0.594	0.950	0.584
~ pdi1	Consistency	0.793	0.207	0.405	0.595	0.197	0.803	0.256	0.744	0.003	0.997	0.006	0.994	0.314	0.686	0.133	0.867	0.003	0.997
	Coverage	0.438	0.320	0.368	0.438	0.436	0.400	0.658	0.359	0.050	0.416	0.050	0.426	0.693	0.342	0.410	0.406	0.050	0.416
pdi2	Consistency	0.704	0.296	0.506	0.494	0.210	0.790	0.134	0.866	0.039	0.961	0.078	0.922	0.110	0.890	0.100	0.900	0.039	0.961
	Coverage	0.611	0.719	0.724	0.571	0.730	0.619	0.543	0.657	0.950	0.631	0.950	0.622	0.381	0.697	0.488	0.662	0.950	0.631
~ pdi2	Consistency	0.795	0.205	0.343	0.657	0.138	0.862	0.200	0.800	0.004	0.996	0.007	0.993	0.316	0.684	0.187	0.813	0.004	0.996
	Coverage	0.389	0.281	0.276	0.429	0.270	0.381	0.457	0.343	0.050	0.369	0.050	0.378	0.619	0.303	0.512	0.338	0.050	0.369
pdi3	Consistency	0.716	0.284	0.517	0.483	0.233	0.767	0.144	0.856	0.046	0.954	0.048	0.952	0.060	0.940	0.055	0.945	0.002	0.998
	Coverage	0.532	0.590	0.632	0.479	0.693	0.515	0.500	0.556	0.950	0.536	0.500	0.550	0.179	0.631	0.230	0.595	0.050	0.561
~ pdi3	Consistency	0.762	0.238	0.363	0.637	0.125	0.875	0.174	0.826	0.003	0.997	0.058	0.942	0.334	0.666	0.224	0.776	0.055	0.945
	Coverage	0.468	0.410	0.368	0.521	0.307	0.485	0.500	0.444	0.050	0.464	0.500	0.450	0.821	0.369	0.770	0.405	0.950	0.439
pdi4	Consistency	0.722	0.278	0.464	0.536	0.207	0.793	0.162	0.838	0.045	0.955	0.068	0.932	0.101	0.899	0.096	0.904	0.002	0.998
	Coverage	0.548	0.590	0.579	0.543	0.629	0.544	0.575	0.556	0.950	0.549	0.725	0.550	0.307	0.616	0.410	0.582	0.050	0.573
~ pdi4	Consistency	0.755	0.245	0.427	0.573	0.155	0.845	0.152	0.848	0.003	0.997	0.033	0.967	0.290	0.710	0.176	0.824	0.057	0.943
	Coverage	0.452	0.410	0.421	0.457	0.371	0.456	0.425	0.444	0.050	0.451	0.275	0.450	0.693	0.384	0.590	0.418	0.950	0.427

Table 3.11: Necessity analysis of main mentors in non-formal R&D firms

Main mentors		*tm*	*~ tm*	*hrdd*	*~ hrdd*	*erdd*	*~ erdd*	*mct*	*~ mct*	*ect*	*~ ect*	*enrd*	*~ enrd*	*pll*	*~ pll*	*fw*	*~ fw*	*ow*	*~ ow*
pdi1	Consistency	0.755	0.245	0.341	0.659	0.150	0.850	0.116	0.884	0.041	0.959	0.047	0.953	0.245	0.755	0.039	0.961	0.047	0.953
	Coverage	0.565	0.565	0.675	0.521	0.693	0.547	0.642	0.556	0.565	0.565	0.437	0.573	0.565	0.565	0.180	0.619	0.437	0.573
~ pdi1	Consistency	0.755	0.245	0.213	0.787	0.086	0.914	0.084	0.916	0.041	0.959	0.079	0.921	0.245	0.755	0.231	0.769	0.079	0.921
	Coverage	0.435	0.435	0.325	0.479	0.307	0.453	0.358	0.444	0.435	0.435	0.563	0.427	0.435	0.435	0.820	0.381	0.563	0.427
pdi2	Consistency	0.750	0.250	0.310	0.690	0.139	0.861	0.123	0.877	0.046	0.954	0.048	0.952	0.264	0.736	0.096	0.904	0.062	0.938
	Coverage	0.634	0.650	0.693	0.616	0.725	0.626	0.770	0.623	0.725	0.634	0.500	0.647	0.688	0.622	0.500	0.657	0.650	0.637
~ pdi2	Consistency	0.763	0.237	0.242	0.758	0.093	0.907	0.065	0.935	0.031	0.969	0.085	0.915	0.211	0.789	0.169	0.831	0.059	0.941
	Coverage	0.366	0.350	0.307	0.384	0.275	0.374	0.230	0.377	0.275	0.366	0.500	0.353	0.313	0.378	0.500	0.343	0.350	0.363
pdi3	Consistency	0.754	0.246	0.334	0.666	0.137	0.863	0.136	0.864	0.060	0.940	0.076	0.924	0.274	0.726	0.095	0.905	0.076	0.924
	Coverage	0.646	0.650	0.757	0.603	0.725	0.636	0.860	0.623	0.950	0.634	0.800	0.637	0.725	0.622	0.500	0.667	0.800	0.637
~ pdi3	Consistency	0.757	0.243	0.197	0.803	0.095	0.905	0.040	0.960	0.006	0.994	0.035	0.965	0.191	0.809	0.173	0.827	0.035	0.965
	Coverage	0.354	0.350	0.243	0.397	0.275	0.364	0.140	0.377	0.050	0.366	0.200	0.363	0.275	0.378	0.500	0.333	0.200	0.363
pdi4	Consistency	0.725	0.275	0.295	0.705	0.112	0.888	0.161	0.839	0.054	0.946	0.056	0.944	0.292	0.708	0.112	0.888	0.073	0.927
	Coverage	0.524	0.613	0.564	0.539	0.500	0.552	0.860	0.510	0.725	0.538	0.500	0.549	0.650	0.512	0.500	0.552	0.650	0.539
~ pdi4	Consistency	0.791	0.209	0.274	0.726	0.135	0.865	0.031	0.969	0.025	0.975	0.067	0.933	0.189	0.811	0.135	0.865	0.047	0.953
	Coverage	0.476	0.388	0.436	0.461	0.500	0.448	0.140	0.490	0.275	0.462	0.500	0.451	0.350	0.488	0.500	0.448	0.350	0.461

After calibration and necessity analysis, datasets are qualified and ready to identify configurations of internal HRM practices, supply chain collaboration, and main mentors 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 truth tables are generated, and they can be refined based on the consistency cutoff and frequency cutoff. The consistency cutoff is set to 0.8, which is the default and minimum values from the software (Ragin, 2008). Software set the default frequency cutoff to 1 (Ragin, 2008), but the frequency cutoff was set to 2. This helps to improve accuracy on configurations for promoting product innovation. Only complex solutions are presented in this study because parsimonious solutions and intermediate solutions make some simplification assumptions on complex solutions (Hsiao et al., 2016; Ragin, 2008; Ragin & Davey, 2016). Details on the parsimonious solutions and intermediate solutions are presented in Appendix C.

3.3.3.5 Coverage values and consistency values

The consistency values and coverage values in fs/QCA can be compared as p-value and R-square value in regression analysis, respectively. Equations (1) and (2) are used to compute the consistency values and coverage values, respectively, where X is the membership scores in causal combination, and Y is the membership scores in the outcome set. Details of the consistency values and coverage values of this study are presented in chapter 5.

$$\textit{Consistency score} = \sum \min(X, Y) \Big/ \sum X \qquad (1)$$

$$\textit{Coverage score} = \sum \min(X, Y) \Big/ \sum Y \qquad (2)$$

3.3.3.6 Sample for result interpretation

To understand how to interpret results from the fs/QCA, an example of configurations that lead firms to achieve high levels and cause firms to result in low levels for the first type of product innovation (pdi1) are provided, as presented in Table 3.12. This table is not the original structure from the fs/QCA. We summarised the results to make them more comprehensive and easier for interpretation.

Table 3.12: Configurations results from the output of fs/QCA

Formal R&D firms (H1f)		Causal conditions				Coverage		Consistency	Solution	
		it	er	pd	qcc	Raw	Unique		Coverage	Consistency
pdi1	A1	○		●	○	0.283	0.127	0.834	0.355	0.796
	A2		●	●	○	0.227	0.072	0.816		
~ pdi1	A3	○	○	○	●	0.211	0.211	0.936	0.211	0.936

Note: ● = presence; ○ = absence; 'Blank' = presence or absence of condition.

The results from Table 3.12 can be interpreted as follows. First, there are three configurations, i.e., A1, A2, and A3 in Table 3.12. The A1 and A2 are the configurations that lead firms to achieve high levels of product innovation. This means firms can achieve high levels of pdi1 when there is [A1: an absence of in-house training, a presence of R&D personnel development, and an absence of quality control circles *(~it, pd, ~qcc)*] OR [A2: a presence of engineer rotation, a presence of R&D personnel development, and an absence of quality control circles *(er, pd, ~qcc)*]. Also firms will result in low levels of product innovation when there is [A3: a presence of quality control circles and an absence of in-house training, engineer rotation, and R&D personnel development *(~it, ~er, ~pd, qcc)*].

Second, we need to interpret the coverage and consistency values. The coverage values are used to measure the percentage of an outcome, covered through a solution (Ragin, 2008). There are three types of coverage, i.e., solution coverage, raw coverage, and unique coverages. From the configurations (A1 and A2) that lead firms to achieve high levels of product innovation, we could interpret the coverage values on the Venn diagram. Solutions coverage is the percentage of an outcome, covered by all configurations [*(A1+A2)*pdi1*]. Similarly, the raw coverage is the share of the outcome, explained by a certain configuration. The raw coverage of A1 is [*A1*pdi1*], and of A2 is [*A2*pdi1*]. Also, the unique coverage is the share of the outcome, exclusively explained by a certain configuration. The unique coverage of A1 is [*A1*(pdi1-A2)*], and of A2 is [*A2*(pdi1-A1)*]. Details of result interpretation is presented in Figure 3.7.

Third, the consistency values are used to measure relationships between a causal condition (or combination of condition) and an outcome. From Ragin (2008), there are two types of consistency, consistency for each configuration and solution consistency. The consistency values need to be higher than 0.7. Simply speaking, the consistency values and coverage values in fs/QCA could be compared as p-value and R-square value in regression analysis, respectively.

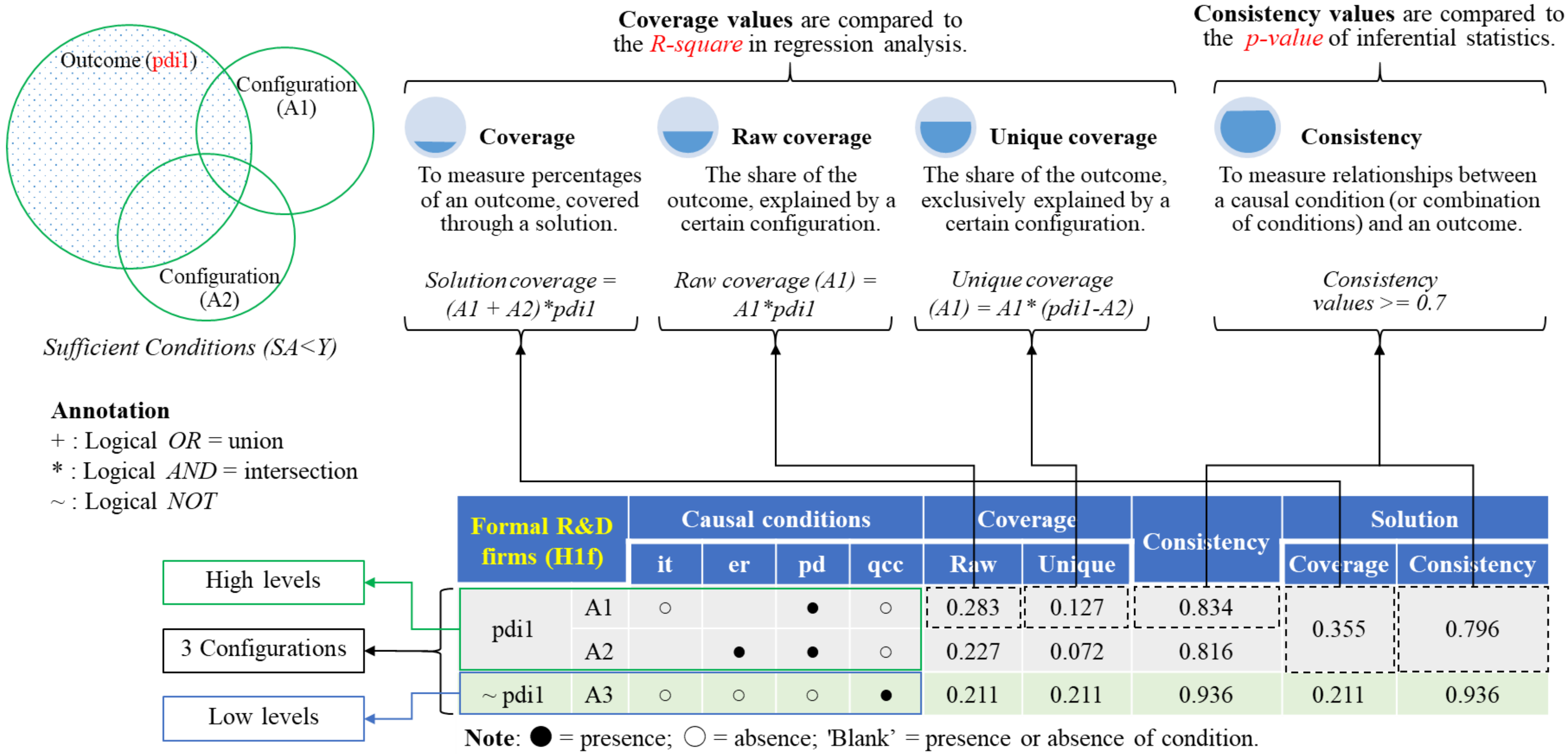

Figure 3.7: Result interpretation

CHAPTER 4
HRM PRACTICES FOR UPGRADING FIRM TECHNOLOGICAL CAPABILITIES

Overview: This chapter investigates HRM practices needed to upgrade firm technological capabilities. Three manufacturing firms, i.e., GGC, Thai Oil, and SCG Chemical, are included in the qualitative analysis because they have successfully upgraded their technological capabilities from the fundamental stage of technology use and operation to the complex stage of R&D. The results from the cross-case comparison indicated that the top management is the main mentors for upgrading firm technological capabilities, where the firms mainly start adopting systematic recruitment and selection, specific training and development, and precise retention and compensation program for HRM. In terms of human capital, firms need highly qualified employees, e.g., master and Ph.D., for upgrading their capabilities to achieve the complex stage of R&D.

4.1 Research background

HRM practices are critical in strengthening firm competitive advantages to penetrate local and international markets. There are various best practices of HRM, which were introduced in the literature review. However, the best practices of HRM tend to vary from one context to another. A single best-practice of HRM in one context may cause problems in another context if top management entirely adopts those practices without understanding contexts of business operation, culture, norm, and value of local employees (Newell et al., 2009). Jørgensen and Becker (2017) stated that there is no one best HRM practice to upgrade firm technological capabilities, and the best HRM practices should align with the context of business operation. Hence, finding the best fit of HRM practices based on our context is more critical than adopting the best practices from outside context (Newell et al., 2009).

For the Thai manufacturing context, Arnold et al. (2000) defined four stages of firm technological capabilities, i.e., technology use and operation, technology acquisition and assimilation, technology upgrading and reverse engineering, and R&D. In their studies, they defined the states of firms for each stage of firm technological capabilities, but they do not identify HRM practices for upgrading firm technological capabilities. For short-term problem-solving, many Thai firms acquired know-how through trial-and-error. Firms implement various common activities to develop their technological capabilities such as on-the-job training, recruiting new employees, introducing kaizen, adopting total quality management, personnel rotation, cross-functional teams, and project-based approach.

For long-term sustainable growths, firms invest in technology and enhance absorptive capability. A valuable resource for upgrading technological capabilities is knowledge. Oltra (2005) and Svetlik and Stavrou-Costea (2007) emphasised knowledge as the most essential and valuable resource of a firm. Consequently, the firms essentially need HRM practices for employee development such that they can improve their organisational commitment (Meyer, Becker, & Vandenberghe, 2004). Budhwar and Debrah (2013) pointed out that employees' skill, capabilities, and experience are essential for corporate success and competitive advantage. Therefore, HRM practices can improve employee skill, knowledge, experiences, and creativities, and these help to improve employee job satisfaction and productivities (Wang, Chiang, & Tung, 2012).

HRM practices consist of cooperation of internal and external resources, where the former may consist of selecting staff and providing job orientation, on-the-job training, and cross-functional teams. The latter help firms to acquire knowledge and may consist of training with suppliers nationally and internationally; R&D outsourcing, e.g., technology acquisition, joint research, and procurement of routine services; and providing scholarships for employees. Both internal and external resources help to enhance firm capabilities for sustainable growth. Thus, HRM practices are a cooperation of internal and external resources, and they are grouped as recruitment and selection, training and development, and retention and compensation.

4.2 Research objectives

The role of skill and tacit knowledge differ across firms and countries depending on firm technological capabilities. This leads us to conduct in-depth case studies to investigate HRM practices for upgrading firm technological capabilities in the Thai manufacturing context. Three firms are purposely selected to include in this qualitative study, i.e., Global Green Chemicals Public Company Limited (GGC), Thai Oil Public Company Limited (Thai Oil), and Siam Cement Group Chemicals Company Limited (SCG Chemicals). Regarding GGC and Thai Oil, the Petroleum Authority of Thailand (PTT) – a state-owned oil and gas company that involved in electricity generation, manufacturing of petrochemical products, oil and gas exploration and production, and gasoline retailing businesses – is their main partner and this company plays an important role for innovation-driven of the two companies.

4.3 Case 1: Global Green Chemicals (GGC)

4.3.1 Background information

Thai Oleochemicals Company Limited was established in July 2005 and renamed as GGC in 2016. It is 100% locally-owned by the PTT Global Chemical Company Limited (PTTGC), and also considered as the green flagship of PTTGC. GGC registered USD 67.9 million as its capital to target local and international markets. In 2016, GGC had around 200 employees, and the annual sales were around USD 260 million. The vision of GGC is to become one of the global leading companies in oleochemicals markets by promoting competitiveness in downstream industries such as producing renewable energy, introducing health and personal care products, and sustaining natural oil industry. The company is the biggest producer of methyl ester (24.9% of market shares) and the only fatty alcohol manufacturer in Thailand. The product innovation of this company is considered as new to the firm because the company expands product types based on current product properties. It provides tailor-made products and packaging designs to enhance customer satisfaction. For quality management systems, quality controls are performed in the laboratory.

4.3.2 Before an establishment of R&D (2005-2010)

In 2006, the GGC set up a joint venture with the Cognis (BASF) Company, Thailand, and founded the Thai Fatty Alcohols Company Limited, to produce fatty alcohols. The company's methyl ester and fatty alcohol plants were constructed under technology licensing from German and Japanese suppliers. This joint venture was set up to expand product varieties and acquire technological knowledge from its partners. The company set up a methyl ester plant in 2007 and commercially run methyl ester and fatty alcohol plants in 2008. During this period, the GGC's technological capabilities relied mostly on technology licensing and technical knowledge transfers from suppliers. The internal and external mechanisms of HRM practices before establishing R&D are presented as follows.

4.3.2.1 Internal mechanisms

GGC provides informal and formal training to develop problem-solving skill for engineers and technical staff. As a subsidiary, the company adopted the human resource policy from the PTTGC. However, the HRM of the firm was not fully developed. The company mainly focused on improving capabilities of engineers and technical staff to improve production processes.

4.3.2.2 External mechanisms

The company purchased licenses for advanced technology and machinery from German and Japanese suppliers. Then engineers and technical staff were trained by foreign experts to handle machinery. They learned how to maintain machinery and equipment and gained technical knowledge from suppliers. They absorbed technical knowledge by training with overseas suppliers through on-the-job training. They also conducted debottlenecking processes to reduce bottlenecks in the production process. These external mechanisms result in improving and achieving high productivity, compared to other companies in the same industry. The company also benefited from a joint venture with Cognis (BASF) Company in terms of new production lines.

4.3.3 After an establishment of R&D (2011-present)

In the first three years of business operation (2005–2008), the company lost USD 17–23 million because its organisational members were new to the business, and business strategies were not appropriate. In 2011, GGC was influenced by Dr. Pailin Chuchottaworn – a new PTT chief executive officer. To enhance business performance and recover revenue, GGC changed business strategies by focusing on cost competition, conducting in-depth market research, setting a clear vision and mutual goals with employees, creating good teamwork, and promoting innovation. The top management encouraged employees to work harder and dedicate themselves to the company's success. From 2011 to 2016, the company gain profits up to USD 22.8–28.5 million. The internal and external mechanisms of HRM practices after establishing R&D are presented as follows.

4.3.3.1 Internal mechanisms

GGC adopted a systematic recruitment system and selection process, by setting high standards to recruit new employees and focusing on young and talented candidates. The company adopts the STAR (Situation, Task, Action, and Result) evaluation principle during an interview process. The applicants should embed with technological knowledge, English, communication, and enthusiasm. They must have a science and technology or engineering background.

Newly recruited employees are required to attend an employee orientation course to introduce the company's history, business functions, and partner information. Then they get one-year intensive training courses on product marketing, product selling, public speaking, and customer services. After training, employees should be able to search for potential customers and negotiate with them. The company improves employees' skill and capabilities by regularly providing them on-the-job and off-the-job training.

The management team encourages employees to voluntarily work harder and collaborate with their colleagues to improve products and processes. For collaboration, the company focuses on employee engagement and cross-functional teams. The marketing and R&D staff need to work together to develop new products, enhance product quality, and improve production processes. Besides, GGC also focuses on training employees in-house and sending them to join training outside.

Information and knowledge are shared across departments through morning meetings, group discussions, and informal circles via Line. Managers have a yearly meeting with employees in the so-called 'MD Town Hall'. In this meeting, the management team shares business performances, the current global market, and updates market trends. The human resource department organises monthly meetings with employees to discuss problems they commonly encounter and analyse impacts of economic situations. Employees from each department are assigned to attend seminars and conferences nationally and internationally.

GGC adopts KPI to evaluate employee performance and adopt reward and recognition systems to encourage employees to find problems and propose solutions. In terms of employee readiness, GGC adopts long-term workforce planning to enhance and improve the efficiency of current human resources. This mainly applied to R&D and engineering groups, who play an important role to drive the company forward. The company also provides career path development to give employees chances to improve skill and capabilities. From this program, employees are monitored regularly, and talented employees could be promoted for future managerial and executive positions.

4.3.3.2 External mechanisms

Before establishing R&D, product specifications were mostly required by PTTGC (80%) and customers (20%). After upgrading their capabilities, the company changed business strategies by focusing on product innovation. The marketing staff conducted in-depth market research with customers to receive feedback and recommendations related to product quality.

They launched questionnaires for customer evaluation related to products and services. After receiving customer requests, R&D teams conducted research and test the new products before launching to the market. As a result, the product was consistently improved to satisfy customer preferences, and the company also expanded markets to downstream customers and diversify production lines to biochemical business.

The top executive and engineering experts were dispatched from PTTGC. They provided valuable advice and transfer knowledge and experiences on petrochemical business to GGC employees. From 2011 to 2016, engineers and technical staff worked under close supervision from the top executives and management teams, so the firms result in successfully expanding production capacity, and significantly increasing in production of methyl ester and fatty alcohol. The company joined research with PTT – at the PTT ECON Industrial Park, Rayong – to strengthen R&D performance. Moreover, GGC also collaborated with local Thai universities, i.e., Maejo University, Chulalongkorn University, and Kasetsart University, by providing internship programs for students. GGC and PTTGC planned to develop a Bio-complex – an industrial park in Nakornsawan province – with plantation areas and manufacturing plants for bioenergy.

4.3.4 HRM practices and policies for promoting innovation

The philosophy of GGC focuses on the development and growth of employees with equal opportunities by building a knowledge-based company. Thus, GGC provides intensive training and development programs to maximise their workforce potential. GGC also has an advanced laboratory and R&D teams with high technical knowledge to design and develop new products and launch them to the market. GGC starts adopting a personal HRM program to ensure that highly qualified personnel are attracted, retained, and equipped with suitable knowledge and expertise to grow well in the future. The company adopts the 10/20/70 principle, with the belief that employees gain knowledge and skill for 10% from training, 20% from supervisor or coach feedback and monitoring, and 70% from applying knowledge and skill to assigned projects and sharing with colleagues. HRM processes are evaluated and improved every three to five years so that the systems stay up to date with the fast-changing of the society. The contribution of supervisors and managers help to ensure that every employee is motivated and determined to accomplish their assigned tasks.

Besides internal practices within the firm, GGC also adopts various external collaborations with supply chain partners to upgrade their technological capabilities and promote innovation. Among partners, customers play a critical role as external sources of knowledge for promoting product and process innovation. Organisational members are trained on services by customers. Marketing and sales personnel need to visit customers regularly to maintain good relationships with current customers and to attract new customers by providing the best customer service, good product quality, and on-time delivery. Employees are required to study customers' profiles and their business details. This approach allows GGC to support its customer's business operations from the beginning and search for business opportunities for each customer. GGC employees share their insight related to the market, business trends, and product prices with customers. These practices help the company to obtain feedback from customers to improve products.

The company also collaborates with suppliers to improve production processes and learn new technologies. Engineers, technicians, and R&D personnel took part in exhibitions, seminars, and conferences related to machinery and equipment, organised by local and foreign suppliers to update their technological knowledge. The employees also receive training from suppliers on equipment and machinery maintenance. Since GGC is a subsidiary of PTTGC – the biggest integrated petrochemical and refining company in Thailand – the company benefits from PTTGC's market positions and reputation related to petrochemical business. GGC rotates engineers and technical staff with PTTGC constantly to improve workforce expertise. GGC also joins R&D with PTTGC. This collaboration does not only help firms for upgrading technological capabilities and promoting innovation but also significantly improve skill and knowledge of R&D personnel and engineers.

4.4 Case 2: Thai Oil

4.4.1 Background information

Thai Oil is a joint venture company, where PTT is the major shareholder (49.1%). Other shareholders comprise foreign investors (25.1%), local investors (20.3%), and non-voting depository receipt holders (5.5%). Thai Oil was established in 1961 as the Oil Refinery Limited. The first investment of PTT in Thai Oil was in 1979. PTT invested USD 571,000 in Thai Oil, to become the major shareholder. In 1985, the company was renamed Thai Oil Public Company Limited, and in 2004, it was registered as a public company. The product of Thai Oil is mainly sold domestically (83%), where only 17% are exported.

Thai Oil has approximately 1,409 employees (300 engineers and 500-600 technical staff), and sales in 2015 were around USD 8.3 billion. Thai Oil is being operated in Thailand, Vietnam, and Singapore. This company produces oil refinery products (275,000 barrels/day), petrochemical and lube base products, power generation, and other products related to transportation services. Its main customers are the Electricity Generating Authority of Thailand, PTT, and other industrial users. Thai Oil focuses on process innovation because of government regulations on product specification for oil refinery products, so Thai Oil has limited new product development.

4.4.2 Before an establishment of R&D (1961-2011)

In 2011, Dr. Pailin Chuchottaworn – a new PTT CEO – proposed a strategic shift by emphasizing innovation for all PTT's business units. This results in modifying the Thai Oil strategy to focus more on innovation. Up to 2011, only five patents were registered under Thai Oil. The internal and external mechanisms of HRM practices before establishing R&D are presented as follows.

4.4.2.1 Internal mechanisms

Thai Oil started the business with its first refinery in 1961 via purchases of technology licenses from many oil licensors, including Shell. The licensors/suppliers provided technical support for the company. The engineers and technical staff of Thai Oil solved problems and propose solutions by adopting trial-and-error methods. This made Thai Oil has a problem-solving culture with the belief that Thai Oil engineers could solve any problems. In 2006, Dr. Viroj Marichak, the Thai Oil president, announced 'POSITIVE – Professional approach, Ownership and commitment, Social responsibility, Integrity, Teamwork and collaboration, Initiative, Visionary focus, and Excellent striving' as organisation culture. This slogan is being adopted by Thai Oil.

4.4.2.2 External mechanisms

Since their technologies were bought from licensors, the Thai Oil employees and engineers had been sent on-the-job training at Shell, Netherlands. The licensors helped to guide the technical teams. Thai Oil did not limit any financial support for overseas training.

4.4.3 After an establishment of R&D (2012-present)

Dr. Pailin Chuchottaworn – a graduate with a Doctor of Engineering in Chemical Engineering from the Tokyo Institute of Technology, Japan – announced his strategy for promoting innovation to sustain the business. After announcing the innovation strategy, he remained the president and CEO of PTT Group until September 2015. With his vision and vast experiences in the petrochemical and refinery business, he established an innovative strategy for sustainable growth and green energy. PTT launched the Technologically Advanced and Green National Oil Company (TAGNOC) project and implemented it in all PTT business units. Thai Oil adopted the strategy by establishing a technical department in 2012 to improve production processes. In 2013, this department was developed to an R&D, innovation, and sustainability department to promote innovation and sustain the business operation.

In 2013, the HRM department of Thai Oil adopted the SPEED-up approach to attract and recruit knowledgeable and competent employees. In 2014, Thai Oil established an R&D laboratory at the National Science and Technology Development Agency (NSTDA) and Chulalongkorn University (CU) to promote innovation and recruit potential newly graduated personnel. The innovation of Thai Oil can be categorised as incremental innovation from problem-solving and radical innovation from the laboratory. Technological capabilities are mainly acquired from suppliers as licensors, project development under contracts with universities, and cross-functional project development. The success of the R&D, innovation, and sustainability development and HRM results in four new patents registration. The internal and external mechanisms of HRM practices after establishing R&D are presented as follows.

4.4.3.1 Internal mechanisms

Thai Oil focuses on smart, good, and loyal employees for promoting innovation, enhancing firm performance, and sustaining a healthy organisation, so newly recruited candidates must have technical skill, experiences, management knowledge, positive attitude, soft skill, and open-mindset to learn and challenge new tasks. Thus, to retrieved qualified candidates, the human resource department changes to proactive strategies by adopting SPEED-up approach – Source by expanding channels to recruit new applicants, Partnership by establishing partnerships with academic institutions, Employer brand by providing equal opportunities to employees to be promoted, Employee referral by providing incentives to employees for recommended qualified applicants, and Driving fast recruitment by improving and fastening recruitment and selection process. The human resource department also adopts '4B' – Building by recruiting new graduates, Buying by hiring young and talented candidates, Borrowing by asking support from supply chain partners, and Bring-in by making contract-based employment (not full-time) – as a sub-strategy approach for recruiting new employees.

4.4.3.2 External mechanisms

For external collaboration with supply chain partners, Thai Oil visits several companies, e.g., 3M Thailand Limited, United Overseas Bank Public Company Limited (UOB Thailand), CP All Public Company Limited, and Du Pont (Thailand) Company Limited, to learn how to promote innovation and sustain the business operation. Thai Oil collaborates with licensors, i.e. Shell, for technical support and technological training. Thai Oil also collaborates with research centres, i.e., NSTDA, and universities, i.e., CU, to set up a laboratory for R&D and to share knowledge and promote innovation. Thai Oil also provides internship and scholarship to employees to further studies at their partners' universities. Thai Oil also invites external professionals to train employees if necessary.

4.4.4 HRM practices and policies for promoting innovation

Thai Oil has precise career path development for employees, e.g., an individual career plan where employees have equal opportunities to be promoted to a higher position depending on their performance. Firms also provide job rotation and various training programs, e.g., on-the-job training, off-the-job training, short training courses, and seminars, to enhance employee capabilities and make them ready for new job assignments. The training is conducted internally and externally by professional trainers at national and international levels. Moreover, Thai Oil provides scholarships for undergraduate students and their employees to pursue higher degrees, e.g., master and doctoral degrees. Besides, Thai Oil also launches Project Innovation 101 for executive training such that they can create an innovation culture in an organisation. From a proactive strategy, Thai Oil evaluates employee performance by using KPI. This company also adopts Plan-Do-Check-Act (PDCA), recognition and reward system, and successor pools to promote employees for managerial positions. Additionally, Thai Oil conducts annual surveys to measure employee engagement with their colleagues for promoting innovation.

4.5 Case 3: Siam Cement Group Chemicals (SCG Chemicals)

4.5.1 Background information

SCG Chemicals is 100% locally-owned with Original Brand Manufacturing (OBM), founded as Cementhai Chemicals Co., Ltd, in 1995. The company was renamed to SCG Chemicals Co., Ltd, in 2006, to serve as holding company to the Siam Cement Group's petrochemical business. SCG Chemicals had around 5,500 employees in 2016, and 20% of them worked in the R&D department. The total revenue in 2016 was approximately USD 5.7 billion. In 2007, 65% and 35% of the produced products were sold to domestic and export markets, respectively. SCG Chemicals is one of Thailand's largest integrated petrochemical companies. It is also a regional market leader and a key industrial producer in the Asia-Pacific region. The philosophy of SCG Chemicals is adherence to fairness, dedication to excellence, belief in values of individuals, and concern for social responsibility.

4.5.2 Before an establishment of R&D (1986-2005)

SCG Chemicals commenced operation in 1983. The company's first plant was set up in 1986. To set up its first plant, the company had to buy licenses from overseas. To expand its production capacity, the company established the second plant in 1997, where they still bought licenses from overseas, but they started building up the plant by themselves. Two years later, they constructed the third plant by themselves without buying licenses from outside. The internal and external mechanisms of HRM practices before establishing R&D are presented as follows.

4.5.2.1 Internal mechanisms

While setting up their first three plants, SCG Chemicals focused on capacity expansion. Thus, they did not have a specific plan to develop human resources. They followed two methods to obtain new knowledge to solve problems. First, they operated their production through learning-by-doing. Second, SCG Chemicals set up its first R&D team along with the third plant. Since they had to develop new products and improve manufacturing processes, they invited professors from overseas to join the team and guide employees to deal with projects.

4.5.2.2 External mechanisms

SCG Chemicals also followed an external collaboration with supply chain partners. The firm joint ventures with foreign firms to obtain technologies. From 1986 to 1999, SCG Chemicals joined ventures with many foreign firms, e.g., Dow Chemicals, Mitsui Chemicals, and Mitsubishi Rayong.

4.5.3 After an establishment of R&D (2006-present)

In 2006, Kan Trakulhoon became the president of SCG. He got first-class honour for his bachelor's degree from CU (Thailand) in electrical engineering. He thereafter pursued his master's degree in engineering and management in the Georgia Institute of Technology, USA. He also studied the Advanced Management Program at Harvard University in 2001. He used to be the president of Cementhai Company Limited from 1999 to 2002. During his presidency, SCG Chemicals set up its own R&D lab in 2006 and established its fourth plant in 2009. The fourth plant was meant to expand its production capacity and supply products to local and international markets. SCG Chemicals registered 350 patents from 2012 to 2015. However, in 2016 alone, they registered 150 patents. The firm mainly adopted the last two steps of technological capabilities, i.e., technology upgrading/reverse engineering and R&D. The internal and external mechanisms of HRM practices after establishing R&D are presented as follows.

4.5.3.1 Internal mechanisms

SCG Chemicals adopts various internal practices for HRM. First, the company improves human resource capabilities by using information and communication technologies for self-learning. These help to improve skill for promoting innovation and expertise for a specific job. The company also launches an innovation leader development plan and initiates an intellectual property management system.

Firms promote innovation atmospheres, e.g., Idea Time sessions, for continuous improvement, where employees are encouraged to share and create new ideas. Employees are encouraged to think out of the box and be open-minded. For example, organisational culture is created to promote common understanding, develop necessary skill for executives, and enable them to be role models for employees to follow. Similarly, they also launch a contest, so-called 'Idea Plus Awards 2006', to promote product and process innovation.

The firm develops R&D competency programs and market research units to provide basic training for employee development. They even provide language proficiency improvement courses to shop floor employees and leadership skill courses to employees in managerial positions so that they would be ready to work overseas. SCG Chemicals provides career orientation programs for newly recruited employees to improve their understanding of the organisational structure and culture. For the new shop floor employees, the firm organises the

Mini C-ChEPS (Constructionism Chemicals Engineering Practice School) to enhance their knowledge and skill before commencing to work.

In 2005, over USD 92 million were invested in R&D to drive innovation in the organisation. The company supports cross-functional team operations such that employees could understand the organisation's goals and share their tacit knowledge. For instance, a learning centre so-called 'The Academy of Operation Excellence' was established. The company also focuses on workforce retention and personnel development by providing scholarships to employees to pursue higher education, e.g., master and Ph.D. degrees, overseas.

4.5.3.2 External mechanisms

SCG Chemicals also adopts various external practices for HRM. The firm collaborates with a local university, King Mongkut's University of Technology, Thonburi, to organise the C-ChEPS program to develop their technicians' problem-solving and analytical skill. SCG Chemicals also invests heavily in R&D to drive new products, and provides different types of training programs by collaborating with professional research institutes; i.e., Pacific Healthcare Co., Ltd; local universities, i.e., CU and Prince Songkla University; international universities, i.e., Oxford University; and government agencies, i.e., The National Innovation Agency. The company also took over a leading innovation and technology company in Norway. Up to now, SCG Chemicals still collaborates with the world's leading companies through joint ventures to access technologies to promote high value-added products.

4.5.4 HRM practices and policies for promoting innovation

SCG Chemicals has a systematic recruitment and selection process for recruiting new employees. The company invites its main customers to be the committee members during interviewing newly recruited employees. SCG Chemicals does not recruit managers from outside because it has career path development. They only promote their internal employees to work in higher positions through KPI. For example, employees can grow through managerial track by becoming supervisors at various levels and up to executive levels of the company, or grow on a specialist track, e.g., researchers or technologists.

SCG Chemicals follows the 10/20/70 principle to develop its human resources such that the employees are ready to work locally and overseas. Here, 10% learning from training, where the company provides internal, external, and international training to their employees; 20% learning from supervisor or coach feedback and monitoring, where the company invites professors from overseas to coach the project staffs; and 70% learning from project assignment or through sharing of knowledge and skill with colleagues, e.g., project-based development, Idea Time sessions, and cross-functional team among marketing and R&D teams.

4.6 Cross-case comparison

There are two parts for cross-case comparison, i.e., (1) firm overview and (2) HRM practices, as presented in Table 4.1 and Table 4.2, respectively.

Table 4.1: Firm overview comparison

Information	GGC	Thai Oil	SCG Chemicals
Type of Investment	• 100% Thai-owned local company (PTTGC)	• Joint venture (PTT 49.1%)	• 100% Thai-owned local company
Sales	• (2016) USD 260 million	• (2015) USD 8.3 billion	• (2015) USD 5.7 billion
R&D Spending	• N/A	• Actual spending 0.5% of sales (Policy: 3%)	• Actual spending 1.6% of sales (Policy: 3%)
Employment	• Around 200 employees	• Engineers: < 300 • Technical staff: 500-600	• 500 employees • 60 Thai Ph.D., • 10 Norway Ph.D., • 6-7 Oxford Post-Doctoral Degree
Main Markets	• Domestic (2016): 100% for methyl ester, 30% for fatty alcohol • Export (2016): 70% for fatty alcohol	• Domestic (2014): 83% • Export (2014): 17%	• Domestic (2007): 65% • Export (2007): 35%
Business History	• Expansion of existing businesses by mergers and acquisitions (M&A) • Expansion of product varieties	• Buy licenses and technology • Develop innovations on their own • Focus on expansion and develop existing production	• Buy licenses and technology • Set up new plant using own technology • Focus on JVs and R&D
Innovation (# of patents)	• Product innovation • Process innovation • N/A	• Process innovation • (9 patents)	• Product innovation • (More than 500 patents)
Main mentors for promoting innovation	• Dr. Pailin Chuchottaworn (PTT) • Top executive • R&D and innovation team	• Dr. Pailin Chuchottaworn (PTT) • Top executive • Engineers • R&D staffs • Suppliers	• Kan Trakulhoon (SCG) • Top executives • Engineers

For the firm overview, as presented in Table 4.1, the GGC and SCG Chemicals are 100% locally-owned firms. Thai Oil Group is a joint venture, with PTT as the main shareholder. These three companies are considered as large firms. The proportion of R&D spending of Thai Oil and SCG Chemicals is 0.5% and 1.6%, respectively, whereas GGC does not have precise budgets for R&D expenditure. The number of patents is an indication for companies to set up their R&D budget. SCG Chemicals registered more than 500 patents, whereas Thai Oil registered only 9 patents. GGC engages in product and process innovation by collaborating with suppliers and customers to improve their product specification and promote new products. In contrast, Thai Oil focuses mainly on process innovation because its products are already specified by the government. Dr. Pailin Chuchottaworn is the main mentor for promoting innovation in PTT Group and its subsidiaries, including GGC and Thai Oil. Mr. Kan Trakulhoon is the main mentor for promoting innovation in SCG Chemicals.

Large companies have good relationships with their partners, especially customers and suppliers, to benefit from research collaboration and technical knowledge transfer. These three firms have good HRM programs to improve their workforce capability. They consider HRM as investments, not costs. They are willing to send their employees to train at and learn from local and international partners. At their initial stages of development, companies used advanced technology and acquired technical knowledge from foreign suppliers via technology licensing. Once they developed knowledge and capabilities, the companies began to develop and improve their factories and production systems by themselves. The top executive is the main mentor for promoting innovation of the organisation. With top-management commitment and support, the employees work harder to generate new ideas for solving problems and promoting innovation.

Each company believes that human capital helps firms to drive competitiveness toward the companies' vision and mission, so they make a huge investment to gain higher knowledge and competencies of their employees. These HRM practices could be categorised as recruitment and selection, training and development, and retention and compensation. Details are presented in Table 4.2.

Table 4.2: Comparison of HRM practices

GGC	Thai Oil	SCG Chemicals
Recruitment and Selection		
• A systematic recruitment system and selection process. • More selective and specific recruitment selection tools.		
• Recruit 'young and talented' candidates	• Recruit 'Smart, Good, Loyal' candidates	• Recruit 'competent and good' people

<table>
<tr><td>• Adopt the STAR (Situation, Task, Action, and Result) evaluation principle for the interview process</td><td>• Adopt the SPEED-up strategy (Source Expansion, Partnership, Employer Brand, Employee Referral, Driving Fast Recruitment)
• Recruitment sub-strategy: 4B (Build, Buy, Borrow, Bring-in)
• Management potential affects hiring decision</td><td>• Hiring committee including internal customers
• Recruit Ph.D. through post-doctoral position (1-year contract)</td></tr>
<tr><td colspan="3">Training and Development</td></tr>
<tr><td colspan="2">• 10/20/70 principle
• Internal, external, and international training
• Cross-functional team (marketing and R&D team)</td><td>• Emphasise the culture of innovation
• Project-based development</td></tr>
<tr><td rowspan="2">• Voluntary workforce and the Idol System
• One-year intensive training course for new recruitment
• PTTGC dispatch top executives to work at GGC</td><td>• Project Innovation 101</td><td>• Idea Time Sessions
• Lab head coaching by overseas professors</td></tr>
<tr><td colspan="2">• Recruitment and R&D collaboration with world-class universities (providing research funding, scholarship, sending their researchers to local and overseas laboratories)</td></tr>
<tr><td colspan="3">Retention and Compensation</td></tr>
<tr><td colspan="2">• Employee evaluation using KPI
• Recognition and reward system for problem-solving and innovation</td><td>• Career path development
• Employee orientation</td></tr>
<tr><td></td><td colspan="2">• Provide master and Ph.D. scholarships to study in leading universities</td></tr>
</table>

For recruitment and selection, the GGC targets to recruit 'young and talented' candidates by adopting the STAR (Situation, Task, Action, and Result) evaluation principle for the interview process. Thai Oil targets to recruit 'Smart, Good, and Loyal' candidates by adopting the SPEED-up strategy (Source Expansion, Partnership, Employer Brand, Employee Referral, Driving Fast Recruitment). Thai Oil also introduces a sub-strategy, so-called 4B (Build, Buy, Borrow, Bring-in), to support in recruiting new employees. Similarly, SCG Chemicals targets to recruit 'competent and good' candidates by hiring committees including internal customers. The SCG also recruits Ph.D. by allowing the candidates to do post-doctoral for one-year contracts. Even though each firm has different programs for recruitment and selection, they mainly use a systematic recruitment system and selection processes to recruit qualified candidates for the right position.

For training and development, each firm adopts the same principle, the so-called 10/20/70 principle. Employees gain knowledge and skill for 10% from training, 20% from supervisor/coach feedback and monitoring, and 70% from their application of knowledge and skill to assigned projects or through knowledge and skill sharing among colleagues. Companies have internal, external, and international training to increase their employees' knowledge and skill. They also adopt cross-functional teams, e.g., marketing and R&D teams, to collect feedback and recommendations from customers. These three companies emphasise how critical innovation culture and encouragement are to change employee mindset toward innovation.

In terms of approaches and systems, GGC uses a voluntary workforce and the Idol System, where the manager acts as a role model for the voluntary transfer of knowledge to their employees. The company also provides one-year intensive training course for newly recruited employees. Since GGC is a subsidiary of PTTGC, PTTGC deputes top executives to work at GGC, the so-called secondment program. This approach allows highly experienced top executives to transfer knowledge and skill to the subsidiary company. Similarly, Thai Oil launches Project Innovation 101 to promote innovation by selecting highly qualified candidates and develop them to be an innovator. SCG Chemicals has Idea Time Sessions, where employees and managers can discuss and exchange ideas. The head of the R&D department is coached by overseas professors from partner universities. Thai Oil and SCG Chemicals have recruitment and R&D collaboration with world-class universities by providing research funding, scholarship, and sending their researchers to local and overseas laboratories.

For retention and compensation, these three companies use KPI for employee evaluation. They also have a recognition and reward systems for employees who solve problems and promote innovation. Career path development is provided to employees to enhance their skill and capabilities continuously. Thai Oil and SCG Chemicals provide master and Ph.D. scholarships for their employees to study in leading universities locally and internationally.

4.7 Conclusions

From case studies, we would like to present similarities and differences in terms of firms' overviews and HRM practices as follows. For the firm overview, these companies are large firms, with a revenue of USD 260 million for GGC, USD 8.3 billion for Thai Oil, and USD 5.7 billion for SCG Chemicals. Their products are sold in the domestic and export markets. For the type of investment, GGC and SCG Chemicals are 100% locally-owned. Only Thai Oil is a joint venture. Thai Oil mainly innovates processes, with 9 patent registrations so far, and SCG Chemicals focuses on product innovations, with more than 500 patents registered during the last five years. However, GGC focuses on both product and process innovation, with no exact number of patent registrations.

There are similarities and differences in terms of HRM practices. For the similarities, first, each firm has a systematic recruitment and selection method with specific criteria to recruit qualified employees. Second, every firm adopts the 10/20/70 principle, where 10% learn from training (internal, external, and international), 20% learn from supervisor or coach feedback and monitoring such as inviting professors from overseas to coach the project, and 70% learn from project assignments or from skill and knowledge sharing from colleagues through project-based development, cross-functional team implementation, and employee orientation. Third, firms evaluate employee performance by using KPI. Outstanding employees in terms of solving problems and promoting innovation are rewarded and promoted through career path development plans.

For differences, first, GGC, Thai Oil, and SCG Chemicals adopted the STAR, SPEED-up, and hiring internal customers as committee members, respectively, for the recruitment and selection process. Second, GGC uses the voluntary workforce and Idol System, whereas Thai Oil and SCG Chemicals created Project Innovation 101 and Idea Time sessions, respectively, for the training and development of their human resources. In addition, Thai Oil and SCG Chemicals also recruited and collaborated with leading universities and research institutes by providing funding, scholarship, and sending researchers to local and overseas laboratories. Third, for retention and compensation, Thai Oil and SCG Chemicals provide master and Ph.D. scholarships to their employees for further studies with leading universities locally and internationally.

From the similarity and differences, we can suggest that, first, the top management needs to set HRM strategies, e.g., recruitment and selection, training and development, and retention and compensation, for promoting innovation. Second, firms also need to continuously improve the capabilities of newly recruited employees and enhance the capabilities of current employees. Third, firms need to adopt a cross-functional team within the department, across the department, and across the firms for employees and engineers such that they can join in various innovative activities for promoting innovation. Fourth, firms need to have a career path development program to develop personnel dedicated for R&D purposes. Fifth, firms should collaborate with supply chain partners to acquire new knowledge and technologies.

From each key milestone, each firm develops its capabilities by using both internal and external resources. Firms can improve their technological capabilities step by step. There are four different stages of firm technological capabilities (Arnold et al., 2000), and each stage requires different types of HRM practices and personnel. From our case study, we can conclude that, first, to move to the first stage of technology use and operation, firms need training from joint venture partners and suppliers for plant setup and operation. Second, for technological acquisition and assimilation, firms need specific recruitment packages and specific plans for training and development. Third, firms need cross-functional teams and project-based teams for innovation before they can upgrade from the second stage to the third stage of technology upgrading and reverse engineering. Lastly, to upgrade to an R&D stage, firms need key R&D gurus, e.g., highly qualified personnel with master and Ph.D. degrees, from internal and external sources.

CHAPTER 5
CONFIGURATIONS OF HRM PRACTICES AND MAIN MENTORS FOR PROMOTING PRODUCT INNOVATION

Overview: This chapter investigates configurations of internal HRM practices, supply chain collaboration, and main mentors that help 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 results are presented in formal and non-formal R&D firms, where the former indicate that (i) R&D personnel development helps formal R&D firms to achieve high levels of product innovation, and if firms do not adopt R&D personnel development, they need to collaborate with customers and suppliers for promoting product innovation; (ii) QCCs do not help firms to achieve high levels of product innovation, but it is somehow helpful after collaborating with customers and suppliers; (iii) QCCs cause firms to result in low levels of product innovation. Even with a presence of customer and supplier collaboration in addition to QCCs, firms still result in low levels of product innovation if they do not adopt in-house training, engineer rotation, and R&D personnel development; and (iv) top management is the main mentors for formal R&D firms, and s/he needs to work with heads of R&D departments to promote product innovation. The latter results on non-formal R&D also indicate that (i) there is no enough evidence to prove how important of R&D personnel development is in achieving high levels of product innovation even with a presence or an absence of customer and supplier collaboration; (ii) QCCs are somehow helpful for firms as shown before and after including customer and supplier collaboration; (iii) firms may result in low levels of product innovation if they do not adopt R&D personnel development. Even with a presence or an absence of customer and supplier collaboration, firms still result in low levels of product innovation if they do not adopt R&D personnel development; and (iv) top management is the main mentors for non-formal R&D firms and s/he needs to work with managers of cross-functional teams to promote product innovation. Thus, the configurations of HRM practices, i.e., internal HRM practices, supply chain collaboration, and main mentors for promoting product innovation need to be adopted differently based on firm technological capabilities.

5.1 Research background

HRM practices for promoting innovation have been extensively studied across continents, countries, and industries (Bello-Pintado, 2015; Bretos, Errasti, & Marcuello, 2018;

McCracken et al., 2017; Monks et al., 2016). In Asia, researchers from, e.g., Thailand (Jeenanunta et al., 2017), India (Mani, 2017), Laos (Norasingh & Southammavong, 2017), Vietnam (Binh & Linh, 2017), Japan (Tsuji et al., 2017b), Philippine (Del Prado & Rosellon, 2017), Singapore (Tsang, 1999), Indonesia (Aminullah et al., 2017), and Malaysia (Mohan, 2017), identified various HRM practices in the manufacturing industry. These studies show that firms mainly realised how critical HRM practices are in creating values for promoting innovation and maintaining the sustainable survival and growth of their organisation in today's fast-changing business environment. However, researchers mainly adopt conventional methods, e.g., regression, correlations, mediators, and moderators, to study effects or relationships between causal conditions and outcomes. For instances, Glaister et al. (2018) defined HRM practices as, i.e., training and development, recruitment and selection, workforce planning, and performance appraisal, and these HRM practices are used as causal conditions to study their effects on firm performance; Ueki (2017) studied roles of top management, internal HRM practices, and customer relationships in promoting innovation of non-formal R&D firms; Zhang et al. (2016) studied relationships between HRM practices and innovation, and identified whether innovation is a mechanism between HRM practices and firm performance. Results from these studies may not fully represent and explain what happens in the workplace, where configurations of HRM practices are related differently for promoting innovation.

Also, researchers mainly stated that their studies are the best practices for HRM, but are they the best for all contexts? For example, Gill and Wong (1998) highlighted five best practices of the Japanese management styles, i.e., lifetime employment, seniority systems, house unions, consensual decision making, and QCCs. These management practices help the Japanese firms to successfully manage, expand, and penetrate their organisations into global markets. Among these practices house unions, consensual decision making, and QCCs are transferable to Singapore, but lifetime employment and seniority systems are problematic in adopting because of cultural differences (Gill & Wong, 1998). 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 contexts of business operation, culture, norm and value of local employees (Newell et al., 2009). Jørgensen and Becker (2017) stated that there is no one best HRM practice for promoting innovation, and the best HRM practices should align with the context of business operation. Hence, this is worth finding the best fit of HRM practices based on our context rather than adopting the best practices from outside contexts (Newell et al., 2009).

Firms mainly adopt HRM practices based on their capabilities, where large firms tend to have stronger capabilities and resources to invest in R&D (Intarakumnerd, Chairatana, & Tangchitpiboon, 2002; Petsas & Giannikos, 2005), and possess innovative advantages over smaller firms in terms of heterogeneous R&D activities (Choi & Lee, 2017). Arnold et al. (2000) defined four stages of firm technological capabilities: technology use and operation, technology acquisition assimilation, technology upgrading and reverse engineering, and R&D. In their studies, they defined the state of firms for each stage of firm technological capabilities, but do not identify HRM practices for promoting innovation. From these four stages of firm technological capabilities, Tsuji et al. (2018) and Intarakumnerd (2017) grouped them into formal R&D firms, which actively has engaged in systematic innovation, have established an R&D department, and/or have allocated budgets for R&D intention, and non-R&D firms, which do not. Thus, HRM practices vary based on firm technological capabilities, so firms need to be treated differently for promoting innovation.

The literature review mainly focuses on factors positively related to an outcome. For example, Ueki (2017) proved that HRM practices help firms to achieve more process innovation, customer relationships help firms to promote product innovation, and top management contributes to promoting product innovation when s/he maintains relationships with engineers. However, are there any configurations that cause firms to result in low levels of product innovation? Therefore, this study reconfigures HRM practices, i.e., internal HRM practices, supply chain collaboration, and main mentors, that lead firms to achieve high levels and cause firms to result in low levels of product innovation in formal and non-formal R&D firms.

5.2 Research objectives

From the case study of Thai manufacturing firms, we highlighted three stages of HRM practices (i) recruitment and selection, (ii) training and development, and (iii) retention and compensation. Across these three stages, we highlight 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 adopt learning-by-doing, knowledge transferred across firms, idea time sessions, (iii) GGC engages employees for voluntary tasks, adopts cross-functional team, conduct internal in-house training, and send employees to train outside. These companies expected that these practices improve employee capabilities, make them ready for new tasks assignment, and change employee mindset toward innovation. These practices help to foster learning and forming a coherent system to facilitate the emergence of innovation at individual, team, and organisation levels (Lin & Sanders, 2017). Hence, the empirical study focuses on in-house training (Sobanke et al., 2014), engineer rotation (Li, Wang, & Liu, 2013), R&D personnel development (González, Miles-Touya, & Pazó, 2016), and QCCs (Watanabe, 1991), as the key causal conditions of internal HRM practices.

From our case studies, the companies highly depend on the downstream and upstream supply chain partners to acquire knowledge for promoting innovation, so suppliers and customers are considered as the key supply chain partner for collaboration in this empirical study. Even the results from case studies highly focus on top management as the main mentors for promoting innovation, we would like to provide empirical evidence by considering employees from various positions as the potential main mentors for promoting innovation.

Therefore, there are three steps in conducting empirical fs/QCA. First, we identify configurations of HRM practices, which consist of in-house training, engineer rotation, R&D personnel development, and QCCs, 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. Second, the supply chain collaboration consists of customer and supplier collaboration is included in addition to the internal HRM practices to identify configurations to achieve high levels and result in low levels of product innovation. Third, we configure the main mentors for promoting product innovation in formal and non-formal R&D firms.

5.3 Theoretical models

Three hypotheses, i.e., H1, H2, and H3, are investigated in this study. Each hypothesis is divided into formal and non-formal R&D firms.

H1: Internal HRM practices (1)

- **H1f**: Configurations of internal HRM practices to achieve high levels and result in low levels for each type of product innovation in formal R&D firms. (1f)
- **H1n**: Configurations of internal HRM practices to achieve high levels and result in low levels for each type of product innovation in non-formal R&D firms. (1n)

H2: Internal HRM practices and supply chain collaboration (2)

- **H2f**. Configurations of internal HRM practices and supply chain collaboration to achieve high levels and result in low levels for each type of product innovation in formal R&D firms. (2f)
- **H2n**. Configurations of internal HRM practices and supply chain collaboration to achieve high levels and result in low levels for each type of product innovation in non-formal R&D firms. (2n)

H3: Main mentors for promoting innovation (3)

- **H3f**. Configurations of main mentors to achieve high levels and result in low levels for each type of product innovation in formal R&D firms. (3f)
- **H3n**. Configurations of main mentors to achieve high levels and result in low levels for each type of product innovation in non-formal R&D firms. (3n)

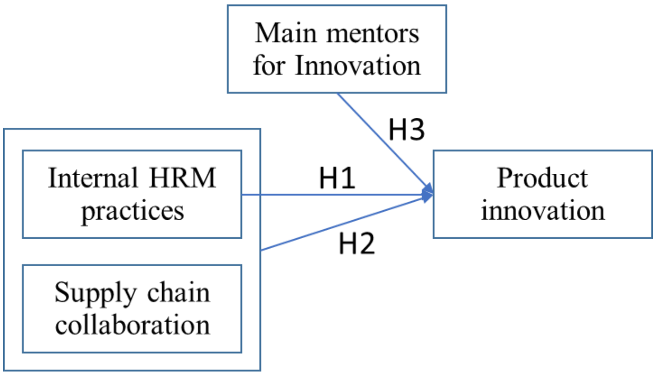

Figure 5.1: Theoretical model

5.4 Results and discussions

5.4.1 Data description

5.4.1.1 Firm basic information

The results show that respondents are mostly locally-owned firms, where 71.4% and 73.7% of them adopt non-formal and formal R&D, respectively. SMEs (employees < 200) from these responded firms mainly have limited capabilities in human resources and financial capital, so they adopt non-formal R&D, whereas large firms (employee >= 200) tend to have higher capabilities to adopt formal R&D for promoting innovation. The results also show how important top management is in non-formal (75.5%) and formal R&D (73.7%) as the main mentor for promoting innovation. Related to their products, firms mainly produced final product (non-formal R&D firms = 53.1% and formal R&D firms = 65.8%), under their own design or drawing (non-formal R&D firms = 73.5% and formal R&D firms = 81.6%). In addition, firms mainly adopt custom-made strategy (non-formal R&D firms = 49.0% and formal R&D firms = 42.1%) to introduce new products to the market. Details on firm information are illustrated in Table 5.1.

Table 5.1: Descriptive statistics of respondents

Description		Non-formal R&D (49)		Formal R&D (38)	
		Freq	Percent	Freq	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
	1,000-1,499	3	6.1	1	2.6
	1,500-1,999	1	2.0	2	5.3
	More than 2,000	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
Mainly produced products at present	Raw materials	8	16.3	3	7.9
	Raw material processing	2	4.1	0	0.0
	Components and parts	13	26.5	10	26.3
	Final products	26	53.1	25	65.8
	Total	49	100.0	38	100.0
Firm produces products under own design or drawing	No	13	26.5	7	18.4
	Yes	36	73.5	31	81.6
	Total	49	100.0	38	100.0
Products released period	Custom-made	24	49.0	16	42.1
	Every 6 months or less	11	22.4	9	23.7
	Every 7-11 months	2	4.1	0	0.0
	Every 1-2 years	10	20.4	7	18.4

Every 3-4 years	0	0.0	3	7.9
Every 5-6 years	0	0.0	1	2.6
Every 7 years or more	1	2.0	2	5.3
System	1	2.0	0	0.0
Total	49	100.0	38	100.0

5.4.1.2 Characteristics of top management

Besides firm basic information, the backgrounds of top management are also investigated as presented in Table 5.2. The results show that top management are mostly Thai (formal R&D = 78.9%, non-formal R&D 85.7%), with an age ranging from 50 to 59-year-old (formal R&D = 50.0%, non-formal R&D = 36.7%). The majority of them hold at least a Bachelor's degree, but they do not have an engineering background (formal R&D = 60.5%, non-formal R&D = 87.8%). Most of these them are the founders of firms (formal R&D = 55.3%, non-formal R&D = 46.9%), but the top management of formal R&D firms tend to have more experiences working for MNCs/JVs firms (57.9%), comparing to non-formal R&D firms (36.7%).

Table 5.2: Characteristics of top management

Top management description		Non-Formal R&D (49)		Formal R&D (38)	
		Frequency	Percent	Frequency	Percent
Country of top management	Thailand	42	85.7	30	78.9
	American	1	2.0	2	5.3
	Holland	0	0.0	1	2.6
	France	1	2.0	0.0	0.0
	Japan	2	4.1	3	7.9
	Malaysia	0	0.0	1	2.6
	Sweden	1	2.0	0.0	0.0
	Taiwan	1	2.0	0.0	0.0
	Total	48	98.0	37.0	97.4
	Missing	1	2.0	1.0	2.6
	Total	49	100.0	38.0	100.0
Ages of top management	20-29 years	2	4.1	2	5.3
	30-39 years	3	6.1	1	2.6
	40-49 years	12	24.5	7	18.4
	50-59 years	18	36.7	19	50.0
	60-69 years	12	24.5	8	21.1
	more than 70 years	1	2.0	1	2.6
	Total	48	98.0	38	100.0
	Missing	1	2.0	0.0	0.0
	Total	49	100.0	38	100.0
Degrees of top management	Bachelor	16	32.7	17	44.7
	Master	18	36.7	12	31.6
	Ph.D.	5	10.2	6	15.8
	Others	10	20.4	3	7.9
	Total	49	100.0	38	100.0

Top management is an engineer	No	43	87.8	23	60.5
	Yes	5	10.2	13	34.2
	Total	48	98.0	36	94.7
	Missing	1	2.0	2	5.3
	Total	49	100.0	38	100.0
Top management is the founder or from the founder's family	Founder	23	46.9	21	55.3
	Inherited family business	13	26.5	10	26.3
	No	13	26.5	7	18.4
	Total	49	100.0	38	100.0
Top management have experience working for MNCs/JVs	No	30	61.2	16	42.1
	Yes	18	36.7	22	57.9
	Total	48	98.0	38	100.0
	Missing	1	2.0	0.0	0.0
	Total	49	100.0	38	100.0

5.4.2 Internal HRM practices

Various configurations of internal HRM practices are identified to achieve high levels and result in low levels (2 levels) for each type of product innovation (4 types of product innovation) in formal and non-formal R&D (2 stages of firm capability). In total, there are 2*4*2 = 16 equations, where 8 equations are tested in formal R&D firms (**H1f**), and another 8 equations are tested in non-formal R&D firms (**H1n**).

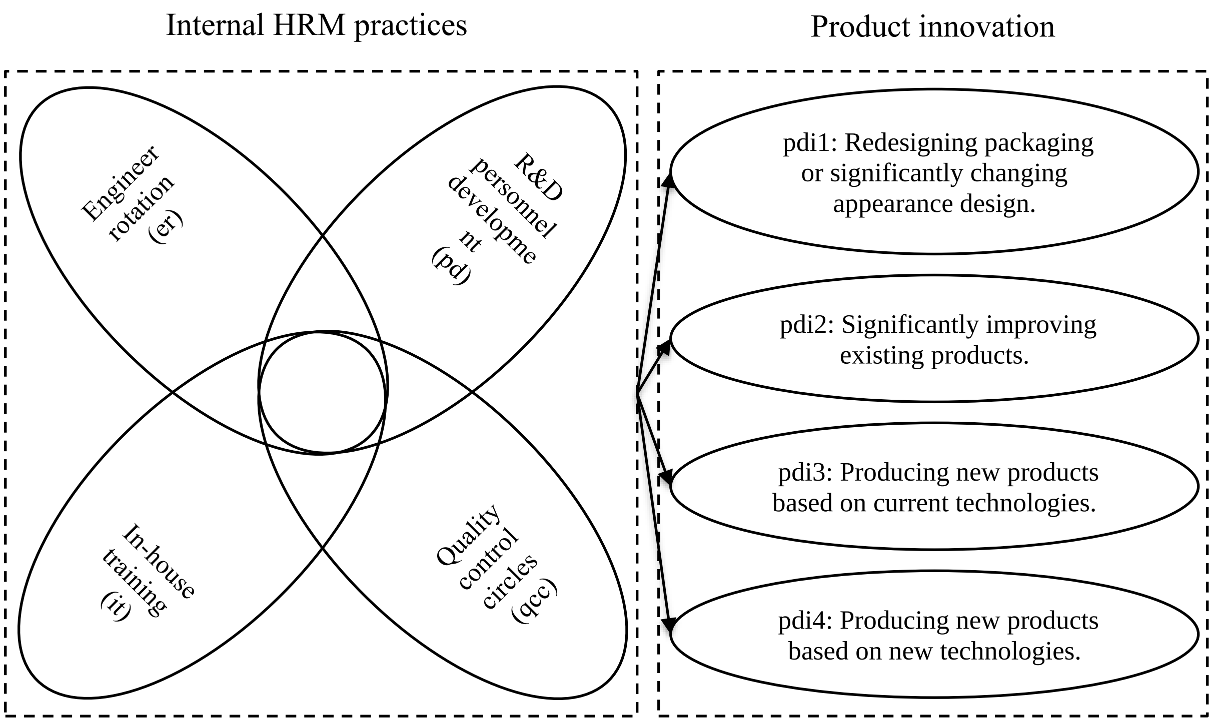

Figure 5.2: Venn diagram of internal HRM practices

5.4.2.1 Formal R&D firms

Various configurations on the combination of causal conditions are proposed by fs/QCA to achieve high levels and result in low levels for each type of product innovation in formal R&D firms, as shown in Table 5.3. The consistency values of these configurations range from 0.784 (B2) to 0.957 (D3). The raw coverage of these configurations ranges from 0.163 (D2) to 0.369 (B1).

The results indicate that, first, firms can achieve high levels of redesigning packaging or significantly changing appearance design (*pdi1*) through two configurations, i.e., (A1) a presence of the R&D personnel development, with an absence of in-house training and QCCs or (A2) a presence of engineer rotation and R&D personnel development, with an absence of QCCs. Second, these two configurations also help firms to achieve high levels in producing new products based on existing technologies (*pdi3*), where (A1 = C1, A2 = C2). Third, there are two configurations for firms to achieve high levels in significantly improving existing products (*pdi2*), i.e., (B1) a presence of R&D personnel development, with an absence of QCCs or (B2) a presence of in-house training and R&D personnel development, with an absence of engineer rotation. Fourth, firms can achieve high levels in producing new products based on new technologies (*pdi4*) by using one of the configurations as presented in *pdi2* (B2 = D1).

However, firms share the same configurations to result in low levels for each type of product innovation *(~pdi1*, *~pdi2*, *~pdi3*, and *~pdi4*). That is when there is a presence of the QCCs, with an absence of in-house training, engineer rotation, and R&D personnel development (A3 = B3 = C3 = D2). In addition, a presence of engineer rotation and R&D personnel development, with an absence of in-house training and QCCs (D3) also causes firms to result in low levels in producing new products based on new technologies (*~pdi4*).

For formal R&D firms, the results indicate that R&D personnel development helps firms to achieve high levels for each type of product innovation, i.e., *pdi1* (A1, A2), *pdi2* (B1, B2), *pdi3* (C1, C2), and *pdi4* (D1). This finding is consistent with Mani (2017), where in-house R&D personnel development is important for promoting innovation. Furthermore, QCCs do not help firms to achieve high levels for each type of product innovation, i.e., *pdi1* (A1, A2), *pdi2* (B1, B2), *pdi3* (C1, C2), and *pdi4* (D1). There is no evidence in the literature review to prove that QCCs do not help firms to promote product innovation, but Machikita, Tsuji, and Ueki (2016) mentioned that QCCs are important for process innovation.

Besides, firms may result in low levels of product innovation if they just adopt QCCs, without adopting in-house training, engineer rotation, and R&D personnel development, i.e., *pdi1* (A3), *pid2* (B3), *pdi3* (C3), and *pdi4* (D2). Hence QCCs do not help firms to achieve any type of product innovation, and if firms still adopt it, they may result in low levels of product innovation.

H1f*: Configurations of internal HRM practices to achieve high levels (pdi) and result in low levels (~ pdi) for each type of product innovation in formal R&D firms.* *(1f)*

This equation can be separated as achieving high levels and resulting in low levels:

Product innovation *= f (In-house training, Engineer rotation, R&D personnel training, Quality control circles)* (1.1f)

AND

~ *Product innovation* *= f (In-house training, Engineer rotation, R&D personnel training, Quality control circles)* (1.2f)

Table 5.3: Configurations of internal HRM practice in formal R&D firms

Formal R&D		Antecedent conditions				Coverage		Consistency	Solution		Cutoff	
		it	*er*	*pd*	*qcc*	Raw	Unique		Coverage	Consistency	Frequency	Consistency
pdi1	A1	○		●	○	0.283	0.127	0.834	0.355	0.796	2	0.810
	A2		●	●	○	0.227	0.072	0.816				
~ *pdi1*	A3	○	○	○	●	0.211	0.211	0.936	0.211	0.936	2	0.936
pdi2	B1			●	○	0.369	0.213	0.816	0.454	0.802	2	0.806
	B2	●	○	●		0.241	0.085	0.784				
~ *pdi2*	B3	○	○	○	●	0.255	0.255	0.936	0.255	0.936	2	0.936
pdi3	C1	○		●	○	0.309	0.138	0.835	0.387	0.796	2	0.816
	C2		●	●	○	0.250	0.078	0.821				
~ *pdi3*	C3	○	○	○	●	0.188	0.188	0.936	0.188	0.936	2	0.936
pdi4	D1	●	○	●		0.283	0.283	0.806	0.283	0.806	2	0.806
~ *pdi4*	D2	○	○	○	●	0.163	0.059	0.864	0.264	0.883	2	0.864
	D3	○	●	●	○	0.205	0.101	0.957				

Note: ● indicates presence of a condition; ○ indicates absence of a condition; 'Blank' indicates presence or absence of a condition.

5.4.2.2 Non-formal R&D firms

Various configurations on the combination of causal conditions are proposed by fs/QCA to achieve high levels and result in low levels for each type of product innovation in non-formal R&D firms, as shown in Table 5.4. The consistency values of these configurations range from 0.764 (O4) to 0.942 (R1). The raw coverage of these configurations ranges from 0.146 (R5) to 0.372 (O5).

The results indicate that, first, firms can achieve high levels of redesigning packaging or significantly changing appearance design (*pdi1*) through three main configurations, i.e., (O1) a presence of engineer rotation with an absence of R&D personnel development and QCCs, (O2) a presence of R&D personnel development with an absence of in-house training and engineer rotation, or (O3) a presence of in-house training, R&D personnel development, and QCCs.

Second, firms can achieve high levels in significantly improving existing products (*pdi2*), by using the same configurations as illustrated in *pdi1* (P1 = O1, P2 = O2, P4 = O3). There is an additional configuration, i.e., a presence of in-house training and QCCs, with an absence of engineer rotation (P3), that can lead firms to achieve high levels of *pdi2*. Third, firms can achieve high levels in producing new products based on existing technologies (*pdi3*) by using one of the configurations, illustrated in *pdi1* (Q1 = O1). There are two additional configurations, i.e., (Q2) a presence of R&D personnel development with an absence of in-house training and engineer rotation or (Q3) a presence of in-house training, engineer rotation, R&D personnel development, and QCCs, that can lead firms to achieve high levels of *pdi3*. Fourth, firms can achieve high levels in producing new products based on new technologies (*pdi4*) by using one of the configurations illustrated in *pdi1* (R1 = O1). There is an additional configuration, i.e., a presence of in-house training and QCCs with an absence of engineer rotation (R2), that can lead firms to achieve high levels of *pdi4*.

However, firms may result in low levels of product innovation through four main configurations, i.e., (i) a presence of QCCs, with an absence of engineer rotation and R&D personnel development (O4 = P5 = Q4 = R4), (ii) a presence of engineer rotation, with an absence of in-house training, R&D personnel development, and QCCs (O6 = P7 = Q6 = R5), (iii) a presence of in-house training and QCCs, with an absence of R&D personnel development (O5 = P6 = R4), and (iv) a presence of in-house training and QCCs, with an absence of engineer rotation (Q5). The first two configurations happen to each type of product innovation, where the configuration three happens to *pdi1*, *pdi2*, *pdi4*, and the configuration four happens only to the *pdi3*.

For non-formal R&D firms, the results indicate that adopting engineer rotation with an absence of R&D personnel development and QCCs, i.e., *pdi1* (O1), *pdi2* (P1), *pdi3* (Q1), and *pdi4* (R1), helps firms to achieve high levels for each type of product innovation. As presented in descriptive statistics, non-formal R&D firms are mostly SMEs, where the majority of them have low capabilities in human and financial capital. Therefore, they cannot afford the R&D department, so this requires them to use engineers and train them for promoting product innovation. Del Prado and Rosellon (2017) mentioned that licensed engineers and experienced personnel are required for technical positions to upgrade innovation. In addition, adopting in-house training, R&D personnel development, and QCCs help firms to achieve high levels of redesigning packaging or significantly changing appearance design, i.e., *pdi1* (O3) and significantly improving existing products, i.e., *pdi2* (P4). Firms can also achieve high levels of producing new products based on existing technologies, i.e., *pdi3* (Q3) if they adopt engineer rotation in addition to in-house training, R&D personnel development, and QCCs. However, there is not enough evidence to show that adopting all these internal HRM practices help firms to produce new products based on new technologies (*pdi4*). This finding is consistent with Norasingh and Southammavong (2017), where concepts for new products derived from knowledge sharing among owners and designers/artisans. After having the product concept, the owners bring those ideas for group discussion and getting feedback over product concepts. Mohan (2017) stated that on-the-job-training, formal internal training, and seminars are critical for promoting innovation.

Besides, there are various configurations caused firms to result in low levels for each type of product innovation, and these configurations show an absence of R&D personnel development, i.e., *pdi1* (O4, O5, O6), *pdi2* (P5, P6, P7), *pdi3* (Q4, Q5, Q6), and *pdi4* (R3, R4, R5). This means that R&D personnel development is critical in promoting product innovation in complementary to other related internal HRM practices. This is also consistent with Santamaría, Nieto, and Barge-Gil (2009), where low and medium technological firms mostly adopt non-formal practices, e.g., designs, utilisation of advanced machinery, and training. They normally cannot afford formal R&D personnel development programs for promoting innovation.

***H1n**: Configurations of internal HRM practices to achieve high levels (pdi) and result in low levels (~ pdi) for each type of product innovation in non-formal R&D firms.* *(1n)*

This equation can be separated as achieving high levels and resulting in low levels:

***Product innovation** = f (In-house training, Engineer rotation, R&D personnel training, Quality control circles)* (1.1n)

AND

~ ***Product innovation** = f (In-house training, Engineer rotation, R&D personnel training, Quality control circles)* (1.2n)

Table 5.4: Configurations of internal HRM practice in non-formal R&D firms

Non-formal R&D		Antecedent conditions				Coverage		Consistency	Solution		Cutoff	
		it	*er*	*pd*	*qcc*	Raw	Unique		Coverage	Consistency	Frequency	Consistency
pdi1	O1		●	○	○	0.163	0.07	0.917	0.56	0.829	2	0.837
	O2	○	○	●		0.31	0.205	0.863				
	O3	●		●	●	0.283	0.169	0.836				
~ *pdi1*	O4		○	○	●	0.341	0.079	0.764	0.48	0.712	2	0.807
	O5	●		○	●	0.372	0.105	0.821				
	O6	○	●	○	○	0.182	0.024	0.833				
pdi2	P1		●	○	○	0.185	0.07	0.936	0.65	0.786	2	0.808
	P2	○	○	●		0.323	0.202	0.811				
	P3	●	○		●	0.236	0.050	0.784				
	P4	●		●	●	0.32	0.137	0.852				
~ *pdi2*	P5		○	○	●	0.329	0.083	0.850	0.45	0.776	2	0.833
	P6	●		○	●	0.345	0.094	0.878				
	P7	○	●	○	○	0.157	0.021	0.833				
pdi3	Q1		●	○	○	0.182	0.079	0.932	0.56	0.841	2	0.862
	Q2	○	○	●		0.328	0.229	0.835				
	Q3	●	●	●	●	0.252	0.142	0.900				
~ *pdi3*	Q4		○	○	●	0.321	0.086	0.815	0.42	0.743	2	0.833
	Q5	●	○		●	0.306	0.072	0.829				
	Q6	○	●	○	○	0.16	0.026	0.833				
pdi4	R1		●	○	○	0.199	0.083	0.942	0.34	0.824	2	0.817
	R2	●	○		●	0.256	0.14	0.797				
~ *pdi4*	R3		○	○	●	0.288	0.06	0.803	0.39	0.721	2	0.833
	R4	●		○	●	0.307	0.075	0.844				
	R5	○	●	○	○	0.146	0.019	0.833				

Note: ● indicates presence of a condition; ○ indicates absence of a condition; 'Blank' indicates presence or absence of a condition.

5.4.2.3 Cross-comparison between formal and non-formal R&D firms

Across formal and non-formal R&D firms, there are three interesting findings. First, R&D personnel development is critical for each type of product innovation in formal R&D firms, but only some configurations of non-formal R&D firms show the critical role of R&D personnel development. Second, the QCCs do not show an important role for each type of product innovation in formal R&D firms, but it is somehow important for promoting product innovation in non-formal R&D firms. Third, there is only one main configuration, causing formal R&D firms to result in low levels for each type of product innovation, which is adopting QCCs, with an absence of in-house training, engineer rotation, and R&D personnel development. However, four configurations cause non-formal R&D firms to result in low levels of product innovation, and those configurations show an absence of R&D personnel development. Therefore, various configurations lead firms to achieve high levels and cause firms to result in low levels for each type of product innovation, and these configurations are different between formal and non-formal R&D firms.

5.4.3 Internal HRM practices and supply chain collaboration

Various configurations of internal HRM practices and supply chain collaboration are identified to achieve high levels and result in low levels (2 levels) for each type of product innovation (4 types of product innovation) in formal and non-formal R&D (2 levels of firm capability). In total, there are 2*4*2 = 16 equations, where 8 equations are tested in formal R&D firms (**H2f**), and another 8 equations are tested in non-formal R&D firms (**H2n**).

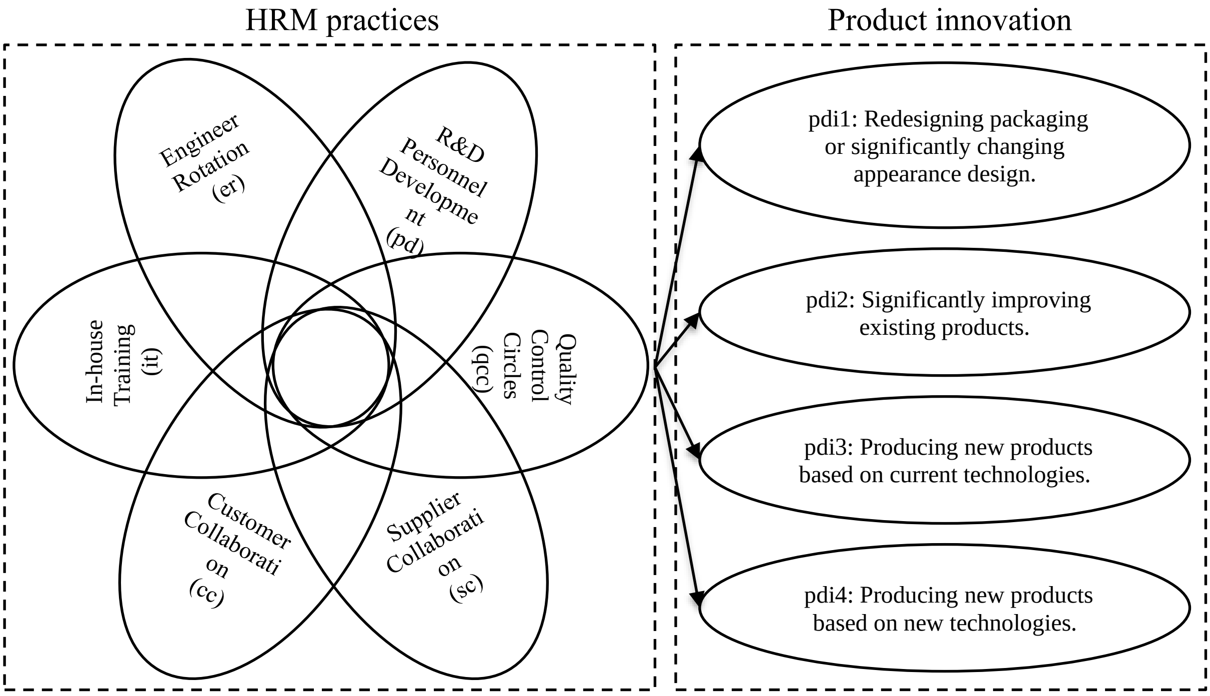

Figure 5.3: Venn diagram of internal HRM practices and supply chain collaboration

5.4.3.1 Formal R&D firms

Various configurations on the combination of causal conditions are proposed by fs/QCA to achieve high levels and result in low levels for each type of product innovation in formal R&D firms, as shown in Table 5.5. The consistency values of these configurations range from 0.807 (E3) to 1.000 (E5). The raw coverage of these configurations ranges from 0.124 (E2) to 0.409 (H4).

Results indicate that, first, there are four main configurations to achieve high levels in (*pdi1*) redesigning packaging or significantly changing appearance design, i.e., (E1) a presence of R&D personnel development, with an absence of in-house training, engineer rotation, QCCs, customers collaboration and supplier collaboration; (E2) a presence of customer collaboration and supplier collaboration, with an absence of in-house training, engineer rotation, R&D personnel development, and QCCs; (E3) a presence of in-house training, R&D personnel development, and QCCs, with an absence of engineer rotation, customer collaboration, and supplier collaboration; or (E4) a presence of in-house training, engineer rotation, R&D personnel development, and supplier collaboration, with an absence of QCCs and customer collaboration. Second, these four configurations also help firms to achieve high levels in (*pdi2*) significantly improving existing products (F1 = E1, F2 = E2, F3 = E3, F4 = E4). Third, firms also share the same configurations in achieving high levels in (*pdi3*) producing new products based on existing technologies (G1 = E1, G2 = E2, G3 = E4) and (*pdi4*) producing new products based on new technologies (H2 = E3, H3 = E4). There are two additional configurations help firms to achieve high levels of *pdi4*, i.e., (H1) a presence of customer collaboration and supplier collaboration, with an absence of in-house training, engineer rotation, and R&D personnel development, or (H4) a presence of in-house training, engineer rotation, R&D personnel development, QCCs, customer collaboration, and supplier collaboration.

However, firms share the same configuration, resulting in low levels of product innovation, i.e., (E5 = F5 = G4 = H7) a presence of QCCs, customer collaboration, and supplier collaboration, with an absence of in-house training, engineer rotation, and R&D personnel development. There are additional two configurations cause firms to result in low levels in (*pdi4*) producing new products based on new technologies, i.e., (H5) an absence of in-house training, engineer rotation, R&D personnel development, QCCs, customer collaboration, and supplier collaboration, or (H6) a presence of in-house training, R&D personnel development, and QCCs, with an absence of engineer rotation, customer collaboration, and supplier collaboration.

For formal R&D firms, the results indicate that firms achieve high levels of product innovation by adopting internal HRM practices, i.e., *pdi1* (E1, E3), *pdi2* (F1, F3), *pdi3* (G1), and *pdi4* (H2); or collaborate with customers and suppliers, i.e., *pdi1* (E2), *pdi2* (F2), *pdi3* (G2), and *pdi4* (H1). More specifically, firms achieve high levels for each type of product innovation when there is a presence of R&D personnel development, i.e., *pdi1* (E1, E3, E4), *pdi2* (F1, F3, F4), *pdi3* (G1, G3), and *pdi4* (H2, H3, H4). 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* (E2), *pdi2* (F2), *pdi3* (G2), and *pdi4* (H1). In addition, firms also achieve high levels for each type of product innovation by combining internal HRM practices (a presence of in-house training, engineer rotation, and R&D personnel development) with supplier collaboration, i.e., *pdi1* (E4), *pdi2* (F4), *pdi3* (G3), and *pdi4* (H3). This means that there are various configurations for promoting product innovation, and firms can do it either internally through internal HRM practices (especially R&D personnel development), externally through supply chain collaboration, or any combinations of them. This finding consistent with Nonaka and Takeuchi (1995), where firms cannot create new knowledge by itself without 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., customer, supplier, university, and external R&D centre collaborations). If firms can leverage resources from external supply chain partners, they tend to be more successful in promoting product innovation (Intarakumnerd, 2017).

The results also indicate that firms achieve high levels in producing new products based on new technologies, i.e., *pdi4* (H4), if firms adopt every type of internal HRM practices and supply chain collaboration. However, if firms miss adopting all these practices, firms result in low levels of producing new products based on new technologies, i.e., *pdi4* (H5). These 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 need to achieve the highest type of product innovation, they need to adopt all HRM practices. The literature also presents how critical HRM practices are, but they do not mention that missing adopting all these practices cause firms to result in low levels of product innovation.

Besides, firms result in low levels of product innovation if they just adopt QCCs, customers, and supplier collaboration, without adopting in-house training, engineer rotation, and R&D personnel development, i.e., *pdi1* (E5), *pdi2* (F5), *pdi3* (G4), and *pdi4* (H7). This configuration is quite similar to the configuration to result in low levels of product innovation before adding supply chain collaboration. This means that adopting QCCs alone or even collaborating with customers and suppliers, firms still result in low levels of product innovation. This shows how critical of other related practices are to spur customer and supplier collaborations for promoting product innovation. Therefore, firms need to have adequate internal capabilities if they want to benefit from supply chain collaboration. Scaringella and Burtschell (2017) stated that being poor in organisational absorptive capacity may result in unsuccessful knowledge transfer from supply chain partners for promoting innovation. In addition, firms may not achieve adequate benefits from internationalisation with supply chain partners if their collaboration linkages are below a threshold (Kafouros et al., 2008).

***H2f**. Configurations of internal HRM practices and supply chain collaboration to achieve high levels (pdi) and result in low levels (~ pdi) for each type of product innovation in formal R&D firms.* *(2f)*

This equation can be separated as achieving high levels and resulting in low levels

Product innovation *= f (In-house training, Engineer rotation, R&D personnel training, Quality control circles, Customer collaboration, supplier collaboration)* (2.1f)

AND

~ *Product innovation* *= f (In-house training, Engineer rotation, R&D personnel training, Quality control circles, Customer collaboration, supplier collaboration* (2.2f)

Table 5.5: Configurations of internal HRM 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	E1	○	○	●	○	○	○	0.241	0.122	0.884	0.368	0.810	2	0.807
	E2	○	○	○	○	●	●	0.124	0.028	0.844				
	E3	●	○	●	●	○	○	0.163	0.048	0.807				
	E4	●	●	●	○	○	●	0.155	0.036	0.919				
~ *pdi1*	E5	○	○	○	●	●	●	0.192	0.192	1.000	0.192	1.000	2	1.000
pdi2	F1	○	○	●	○	○	○	0.236	0.117	0.966	0.383	0.940	2	0.910
	F2	○	○	○	○	●	●	0.131	0.036	1.000				
	F3	●	○	●	●	○	○	0.164	0.057	0.910				
	F4	●	●	●	○	○	●	0.151	0.040	1.000				
~ *pdi2*	F5	○	○	○	●	●	●	0.232	0.232	1.000	0.232	1.000	2	1.000
pdi3	G1	○	○	●	○	○	○	0.256	0.123	0.861	0.355	0.874	2	0.861
	G2	○	○	○	○	●	●	0.160	0.043	1.000				
	G3	●	●	●	○	○	●	0.170	0.056	0.927				
~ *pdi3*	G4	○	○	○	●	●	●	0.171	0.171	1.000	0.171	1.000	2	1.000
pdi4	H1	○	○	○		●	●	0.187	0.089	0.839	0.606	0.781	2	0.807
	H2	●	○	●	●	○	○	0.187	0.041	0.807				
	H3	●	●	●	○	○	●	0.182	0.052	0.937				
	H4	●	●	●	●	●	●	0.409	0.278	0.813				
~ *pdi4*	H5	○	○	○	○	○	○	0.288	0.184	0.862	0.438	0.820	2	0.812
	H6	●	○	●	●	○	○	0.203	0.095	0.812				
	H7	○	○	○	●	●	●	0.158	0.051	0.980				

Note: ● indicates presence of a condition; ○ indicates absence of a condition; 'Blank' indicates presence or absence of a condition.

5.4.3.2 Non-formal R&D firms

Various configurations on the combination of causal conditions are proposed by fs/QCA to achieve high levels and result in low levels for each type of product innovation in non-formal R&D firms, as shown in Table 5.6. The consistency values of these configurations range from 0.741 (T1) to 0.957 (T7). The raw coverage of these configurations ranges from 0.145 (T2) to 0.340 (S5).

Results indicate that, first, firms achieve high levels in (*pdi1*) redesigning packaging or significantly changing appearance design in four configurations, i.e., (S1) a presence of in-house training with an absence of R&D personnel development, QCCs, customer collaboration, and supplier collaboration; (S2) a presence of R&D personnel development with an absence of in-house training, engineer rotation, customer collaboration, and supplier collaboration; (S3) a presence of in-house training and engineer rotation, with an absence of R&D personnel development, customer collaboration, and supplier collaboration; or (S4) a presence of in-house training, engineer rotation, R&D personnel development, QCCs, customer collaboration, and supplier collaboration. Second, firms achieve high levels of (*pdi2*) significantly improving existing products by five different configurations, where three of these configurations are the same (T3 = S2, T4 = S3, T5 = S4). There are two additional configurations in achieving high levels of *pdi2*, i.e., (T1) an absence of engineer rotation, R&D personnel development, QCCs, customer collaboration, and supplier collaboration; or (T2) a presence of in-house training, QCCs, customer collaboration, and supplier collaboration, with an absence of engineer rotation and R&D personnel development. Third, firms share the same configurations (U1 = S2, U2 = S3, U3 = S4) in achieving high levels of (*pdi3*) producing new products based on new technology. Fourth, firms only share two same configurations (V2 = S3, V4 = S4) in achieving high levels of (*pdi4*) producing new products based on new technology. There are two additional configurations in achieving high levels of pdi4, i.e., (V1) a presence of R&D personnel development and QCCs, with an absence of in-house training, engineer rotation, customer collaboration, and supplier collaboration; or (V3) a presence of in-house training, QCCs, customer collaboration, and supplier collaboration, with an absence of engineer rotation and R&D personnel development.

Firms, however, result in low levels of (*pdi1*) redesigning packaging or significantly changing appearance design in two main configurations, i.e., (S5) a presence of in-house training, QCCs, customer collaboration, and supplier collaboration, with an absence of R&D personnel development, or (S6) a presence of in-house training, engineer rotation, and QCCs, with an absence of R&D personnel development, customer collaboration, and supplier collaboration. These two configurations also cause firms to result in low levels of product innovation in (*pdi2*) significantly improving existing products (T6 = S5, T7 = S6), (*pdi3*) producing new products based on existing technologies (U4 = S5, U5 = S6), and (*pdi4*) producing new products based on new technologies (V5 = S5, V6 = S6). In addition, there is one more configuration that causes firms to result in low levels of *pdi3*, i.e., (U6) a presence of in-house training, with an absence of engineer rotation, R&D personnel development, QCCs, customer collaboration, and supplier collaboration.

For non-formal R&D firms, the results indicate that firms can achieve high levels of redesigning packaging or significantly changing appearance design, i.e., *pdi1* (S1), and significantly improving the current product, i.e., *pdi2* (T1), 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* (U6). In addition, it is common that if firms are capable to adopt every HRM practice, they can achieve high levels for each type of product innovation, i.e., *pdi1* (S4), *pdi2* (T5), *pdi3* (U3), and *pdi4* (V4). This means that firms mainly 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 organisation (Newell et al., 2009). However, non-formal R&D firms are mostly SMEs, as presented in descriptive statistics, and they have limited financial resources, low technological capabilities, insufficient infrastructure, and low managerial skill (Sudhir Kumar & Bala Subrahmanya, 2010). Hence, they mostly try to achieve high levels of product innovation internally without customer and supplier collaboration, i.e., *pdi1* (S2, S3), *pdi2* (T3, T4), *pdi3* (U1, U2), *pdi4* (V1, V2). 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, QCCs, customer, and supplier collaboration, without adopting engineer rotation and R&D personnel development, i.e., *pdi1* (S5), *pdi2* (T6), *pdi3* (U4), and *pdi4* (V5); or they just adopt in-house training, engineer rotation, and QCCs, without adopting R&D personnel development, customer, and supplier collaboration, i.e., *pdi1* (S6), *pdi2* (T7), *pdi3* (U5), and *pdi4* (V6). Therefore, various configurations cause firms to result in low levels of product innovation, and in specific those configurations show that adopting in-house training without R&D personnel development always causes firms to result in low levels for each type of product innovation even with or without customer and supplier collaboration.

H2n. *Configurations of internal HRM practices and supply chain collaboration to achieve high levels (pdi) and result in low levels (~ pdi) for each type of product innovation in non-formal R&D firms.* *(2n)*

This equation can be separated as achieving high levels and resulting in low levels:

Product innovation *= f (In-house training, Engineer rotation, R&D personnel training, Quality control circles, Customer collaboration, supplier collaboration)* (2.1n)

AND

~ *Product innovation* *= f (In-house training, Engineer rotation, R&D personnel training, Quality control circles, Customer collaboration, supplier collaboration* (2.2n)

Table 5.6: Configurations of internal HRM practice 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	S1	●		○	○	○	○	0.225	0.088	0.873	0.521	0.854	2	0.851
	S2	○	○	●		○	○	0.253	0.169	0.889				
	S3	●	●	○		○	○	0.166	0.023	0.941				
	S4	●	●	●	●	●	●	0.190	0.096	0.861				
~ pdi1	S5	●		○	●	●	●	0.340	0.191	0.925	0.364	0.876	2	0.841
	S6	●	●	○	●	○	○	0.173	0.024	0.841				
pdi2	T1		○	○	○	○	○	0.328	0.164	0.741	0.662	0.745	2	0.801
	T2	●	○	○	●	●	●	0.145	0.029	0.836				
	T3	○	○	●		○	○	0.266	0.139	0.841				
	T4	●	●	○		○	○	0.181	0.029	0.926				
	T5	●	●	●	●	●	●	0.218	0.102	0.892				
~ pdi2	T6	●		○	●	●	●	0.295	0.166	0.924	0.336	0.932	2	0.918
	T7	●	●	○	●	○	○	0.171	0.041	0.957				
pdi3	U1	○	○	●		○	○	0.287	0.194	0.921	0.483	0.872	2	0.873
	U2	●	●	○		○	○	0.175	0.075	0.905				
	U3	●	●	●	●	●	●	0.214	0.111	0.886				
~ pdi3	U4	●		○	●	●	●	0.274	0.140	0.846	0.411	0.765	2	0.813
	U5	●	●	○	●	○	○	0.152	0.001	0.841				
	U6	●	○	○	○	○	○	0.251	0.116	0.820				
pdi4	V1	○	○	●	●	○	○	0.181	0.079	0.897	0.421	0.802	2	0.804
	V2	●	●	○		○	○	0.191	0.082	0.910				
	V3	●	○	○	●	●	●	0.149	0.039	0.804				
	V4	●	●	●	●	●	●	0.219	0.098	0.835				
~ pdi4	V5	●		○	●	●	●	0.265	0.145	0.895	0.303	0.907	2	0.883
	V6	●	●	○	●	○	○	0.158	0.038	0.957				

Note: ● indicates presence of a condition; ○ indicates absence of a condition; 'Blank' indicates presence or absence of a condition.

5.4.3.3 Cross-comparison between formal and non-formal R&D firms

Comparing formal and non-formal R&D firms, we have four main findings. 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 still 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. 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 a 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 roles of R&D personnel development to achieve high levels of product innovation, but the results indicate that an absence of R&D personnel development causes non-formal R&D firms to result in low levels of product innovation. Third, there is no precise evidence to make conclusions on the roles of QCCs in formal and non-formal R&D firms because it somehow leads firms to achieve high levels and causes firms to result in low levels of product innovation. Finally, formal R&D firms result in low levels of product innovation if they just adopt QCCs, customer, 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, and even with or without customer and supplier collaboration.

5.4.4 Main mentors for promoting innovation

Various configurations of main mentors are identified to achieve high levels and result in low levels (2 levels) for each type of product innovation (4 types of product innovation) in formal and non-formal R&D (2 levels of firm capability). In total, there are 2*4*2 = 16 equations, where 8 equations are tested in formal R&D firms (**H3f**), and another 8 equations are tested in non-formal R&D firms (**H3n**).

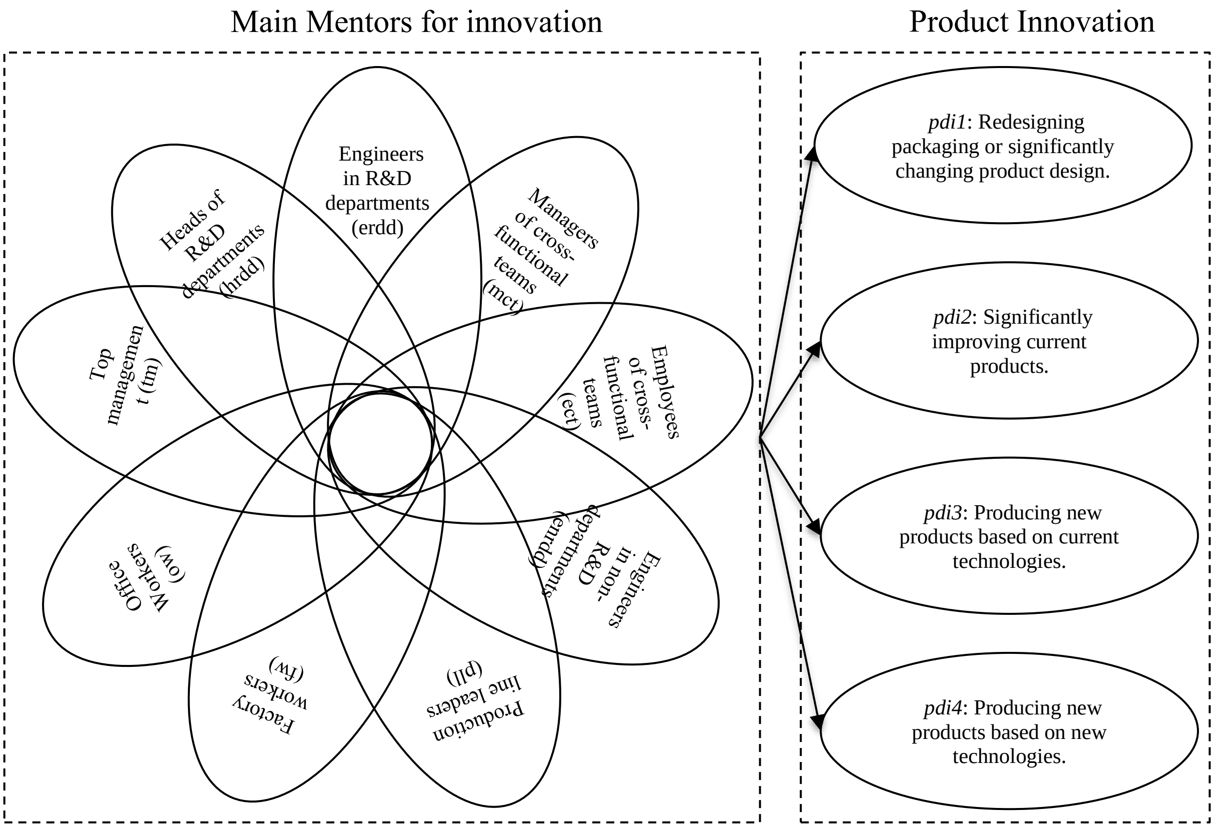

Figure 5.4: Venn diagram of main mentors for promoting innovation

5.4.4.1 Formal R&D firms

There are three configurations of combining causal conditions to achieve high levels of the first three types of product innovation in formal R&D firms, as shown in Table 5.7. Each configuration has a consistency score of 0.95, and the raw coverage of 0.209, 0.187 to 0.228 for *pdi1*, *pdi2*, and *pdi3*, respectively.

Formal R&D firms can achieve high levels of redesigning packaging or significantly changing product design (*pdi1*), significantly improving existing products (*pdi2*), and producing new products based on current technologies (*pdi3*) when there is a presence of the top management and heads of R&D departments, but with an absence of engineers in R&D departments, managers of cross-functional teams, employees of cross-functional teams, engineers in non-R&D departments, production line leaders, factory workers, and office workers. There is no configuration that leads firms to achieve high levels in producing new products based on new technologies (*pdi4*) and no configuration that causes firms to result in low levels for each type of product innovation.

This means that ideas for product innovation in formal R&D firms are mainly initialised by the top management in collaboration with the heads of R&D departments. However, there is not enough evidence to prove how important top management and heads of R&D departments are in achieving high levels of new products based on new technology. The descriptive statistics in this study show that formal R&D firms are mostly large firms with high capability to expose to the outside world, e.g., collaboration with supply-chain partners, research centres, and universities, to obtain advanced technological knowledge (Belderbos, Carree, & Lokshin, 2004). If firms can leverage resources from external supply chain partners, they tend to be more successful in promoting product innovation (Intarakumnerd, 2017).

This does not mean that ideas from other individuals are not critical or make firms less innovative, but ideas for innovation are mainly initialised by top management with heads of R&D departments. Ideas proposed by other employees tend to be complementary because there are no configuration that cause firms to result in low levels for each type of product innovation. From the literature review, researchers mostly highlight how crucial the top management for product innovation is in formal R&D firms (Binh & Linh, 2017), but they do not identify who the main co-mentors are for such innovation.

H3f. Configurations of main mentors to achieve high levels (*pdi*) and result in low levels (~ *pdi*) for each type of product innovation in formal R&D firms. (3f)

This equation can be separated as achieving high levels and resulting in low levels:

Product Innovation= *f (Top management, Heads of R&D departments, Engineers in R&D departments, Managers of cross-functional teams, Employees of cross-functional teams, Engineers in non-R&D departments, Production line leaders, Factory workers, Office workers)* (3.1f)

AND

~ *Product innovation* *f (Top management, Heads of R&D departments, Engineers in R&D departments, Managers of cross-functional teams, Employees of cross-functional teams, Engineers in non-R&D departments, Production line leaders, Factory workers, Office workers)* (3.2f)

Table 5.7: Configurations of main mentors in formal R&D firms

configurations in formal R&D		Antecedent conditions									Coverage		Consistency	Solution		Cutoff	
		tm	*hrdd*	*erdd*	*mct*	*ect*	*enrdd*	*pll*	*fw*	*ow*	Raw	Unique		Coverage	Consistency	Frequency	Consistency
pdi1	I1	●	●	○	○	○	○	○	○	○	0.209	0.209	0.950	0.209	0.950	3	0.950
~ *pdi1*	N/A																
pdi2	J1	●	●	○	○	○	○	○	○	○	0.188	0.188	0.950	0.188	0.950	3	0.950
~ *pdi2*	N/A																
pdi3	K1	●	●	○	○	○	○	○	○	○	0.228	0.228	0.950	0.228	0.950	3	0.950
~ *pdi3*	N/A																
pdi4	N/A																
~ *pdi4*	N/A																

Note: ● indicates presence of a condition; ○ indicates absence of a condition; 'Blank' indicates presence or absence of a condition.

5.4.4.2 Non-formal R&D firms

There are four configurations of combining causal conditions to achieve high levels of each type of product innovation in non-formal R&D firms, as shown in Table 5.8, where the consistency values of each configuration are 0.95. The raw coverage of these four configurations are 0.064, 0.071, 0069, and 0.075 for *pdi1*, *pdi2*, *pdi3*, and *pdi4*, respectively.

Non-formal R&D firms can achieve high levels of redesigning packaging or significantly changing product design (*pdi1*), significantly improving existing products (*pdi2*), producing new products based on current technologies (*pdi3*), and producing new products based on new technologies (*pdi4*) when there is a presence of top management and managers of cross-functional teams, but with an absence of heads of R&D departments, engineers in R&D departments, employees of cross-functional teams, engineers in non-R&D departments, production line leaders, factory workers, and office workers. There is also no configuration that causes firms to result in low levels for each type of product innovation.

This means that the main mentors for promoting product innovation in non-formal R&D firms are top management in collaboration with managers of cross-functional teams. They may initialise ideas for promoting product innovation for employees to implement. Top management does not work with the heads of R&D departments because non-formal R&D firms may not have an R&D department. This is why they do not allocate budgets for R&D activities. This does not mean that ideas from other employees are not important, but that ideas for promoting product innovation are mainly initialised by top management in collaboration with managers of cross-functional teams. Ideas proposed by other employees tend to be complementary because there is no configuration that causes firms to result in low levels for each type of product innovation in non-formal R&D firms.

From the literature review, researchers highlighted how critical top management is for promoting product innovation in non-formal R&D firms (Aminullah et al., 2017; Norasingh & Southammavong, 2017), but these papers did not identify the co-mentors for promoting product innovation. The results of this study are consistent with those by Ueki (2017), who mentioned how important top management is for promoting product innovation in non-formal R&D firms. However, there is a contradiction in terms of co-mentors. Ueki (2017) presented how important top management is in developing mentoring relationships with their engineers, but this research showed how important top management is in developing mentoring relationships with managers of cross-functional teams to achieve each type of product innovation.

H3n. Configurations of main mentors to achieve high levels (*pdi*) and result in low levels (~ *pdi*) for each type of product innovation in non-formal R&D firms. (3n)

This equation can be separated as achieving high levels and resulting in low levels

Product Innovation= *f (Top management, Heads of R&D departments, Engineers in R&D departments, Managers of cross-functional teams, Employees of cross-functional teams, Engineers in non-R&D departments, Production line leaders, Factory workers, Office workers)* (3.1n)

AND

~ *Product innovation* *f (Top management, Heads of R&D departments, Engineers in R&D departments, Managers of cross-functional teams, Employees of cross-functional teams, Engineers in non-R&D departments, Production line leaders, Factory workers, Office workers)* (3.2n)

Table 5.8: Configurations of main mentors in non-formal R&D firms

configurations in non-formal R&D		Antecedent conditions									Coverage		Consistency	Solution		Cutoff	
		tm	*hrdd*	*erdd*	*mct*	*ect*	*enrdd*	*pll*	*fw*	*ow*	Raw	Unique		Coverage	Consistency	Frequency	Consistency
pdi1	W1	●	○	○	●	○	○	○	○	○	0.064	0.064	0.950	0.064	0.950	2	0.950
~ *pdi1*	N/A																
pdi2	X1	●	○	○	●	○	○	○	○	○	0.071	0.071	0.950	0.071	0.950	2	0.950
~ *pdi2*	N/A																
pdi3	Y1	●	○	○	●	○	○	○	○	○	0.070	0.070	0.950	0.070	0.950	2	0.950
~ *pdi3*	N/A																
pdi4	Z1	●	○	○	●	○	○	○	○	○	0.076	0.076	0.950	0.076	0.950	2	0.950
~ *pdi4*	N/A																

Note: ● indicates presence of a condition; ○ indicates absence of a condition; 'Blank' indicates presence or absence of a condition.

5.4.4.3 Cross-comparison between formal and non-formal R&D firms

Across formal and non-formal R&D firms, the results indicate two interesting findings. First, top management plays a critical role as the main mentor for promoting product innovation in both formal and non-formal R&D firms (Jeenanunta et al., 2017; Mohan, 2017). Top management is the main factor for success and failure in HRM and technological advancement (Intarakumnerd, 2017). The results also indicate how important top management is in mentoring relationships with heads of R&D departments for formal R&D firms and managers of cross-functional teams for non-formal R&D firms. The manufacturing firms in Thailand mainly adopt top-down management, where top management plays a critical role in knowledge exploration and exploitation for promoting product innovation. Product development needs to be supported by related employees, i.e., top management chooses to work with heads of R&D departments and managers of cross-functional teams for formal and non-formal R&D firms, respectively. Top management from formal R&D firms chooses to work with heads of R&D departments because such departments are created for the purpose of innovation. Ideas from heads of R&D departments tend to be critical for promoting product innovation. This is different from non-formal R&D firms that may not have an R&D department. This requires top management to collaborate with managers of cross-functional teams instead. Second, no configuration causes firms to result in low levels of product innovation, so ideas proposed by employees from other departments do not prevent or slow firms from achieving product innovation. Ideas from related employees tend to be complementary to the main mentors' ideas. This is consistent with that of Watanabe (1991), i.e., knowledge for innovation is embedded with every individual from management positions to ordinary employees inside an organisation. Even if they do not initialise ideas for promoting product innovation, they implement ideas proposed by the main mentors.

5.5 Conclusions

Sources of knowledge for promoting innovation tend to vary from one context to another. This leads us to conduct an empirical study, consists of three steps, i.e., (1) using only internal HRM practices as causal conditions, (2) using supply chain collaboration in addition to internal HRM practices as causal conditions, and (3) using main mentors as causal conditions, to identify various configurations to achieve high levels and result in low levels for each type of product innovation in formal and non-formal R&D firms. The data were collected during December 2016 - February 2017, from manufacturing firms, located in the Bangkok metropolitan area. The target respondents are the key person 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 fs/QCA.

From these three steps of empirical analysis, the results are summarised in formal and non-formal R&D firms as follows. For formal R&D firms, the results indicate four main findings, i.e., (1) R&D personnel development help firms to achieve high levels of product innovation, and if firms do not adopt R&D personnel development, they need to collaborate with customers and suppliers; (2) QCCs do not help firms to achieve high levels of product innovation, but it is somehow helpful after including supply chain collaboration; (3) QCCs cause firms to result in low levels of product innovation. Even with a presence of customer and supplier collaboration in addition to QCCs, formal R&D firms still result in low levels of product innovation if they do not adopt in-house training, engineer rotation, and R&D personnel development; and (4) top management is the main mentors for promoting product innovation, and s/he needs to work with heads of R&D departments.

For non-formal R&D firms, the results also indicate four main findings: (1) there is no enough evidence to prove how important of R&D personnel development is in achieving high levels of product innovation even with a presence or an absence of customer and supplier collaboration; (2) QCCs are somehow helpful for firms to achieve product innovation as shown before and after including supply chain collaboration; (3) firms may result in low levels of product innovation if they do not adopt R&D personnel development. Even with a presence or an absence of customer and supplier collaboration, R&D firms still results in low levels of product innovation if they just adopt in-house training, without R&D personnel development; and (4) top management is the main mentors for promoting product innovation, and s/he needs to work with managers of cross-functional teams.

Across formal and non-formal R&D firms, first, firms should adopt R&D personnel development such that they can achieve more product innovation. If firms do not adopt R&D personnel development, they should at least collaborate with customers and suppliers to acquire knowledge for promoting innovation. Even some configurations in non-formal R&D firms do not show precise evidence on the significance of R&D personnel development for promoting product innovation, but firms mainly result in low levels of product innovation if they do not adopt R&D personnel development. Second, adopting only QCCs may cause firms to result in low levels in promoting product innovation, so firms should adopt other related practices, e.g., in-house training, engineer rotation, R&D personnel development, or collaborate with supply chain partners. Third, the top-management is recognised as the main mentors for promoting innovation, and this study proves that the top management also works with heads of R&D departments for formal R&D firms and managers of cross-functional teams for non-formal R&D firms for promoting product innovation.

CHAPTER 6
DISCUSSIONS

Overview: This chapter discusses the findings to respond the SRQs and MRQ. This study uses mixed methods, which is the adoption of the qualitative approach, as presented in Chapter 3, to respond the SRQ1 and SRQ2, and the adoption of fs/QCA, as presented in Chapter 4, to respond the SRQ3 and SRQ4. Then we compromise our findings to respond the MRQ. The findings are summarised in the research framework.

6.1 A qualitative analysis

The qualitative analysis is conducted to answer SRQ1 and SRQ2 by using in-depth case studies with the Thai manufacturing firms, which experience transition in upgrading their technological capabilities from non-formal and formal R&D firms. Responses to SRQ1 and SRQ2 are presented as follows.

SRQ1: What types of HRM practices are needed to upgrade firm technological capabilities?

Firms adopt HRM practices to manage their employees such that they can stay competitive in their business environment, upgrade firm technological capabilities, promote innovation, and enhance performance. HRM practices needed to be considered as a chain, so this study considers three processes of HRM practices, i.e., recruitment and selection, training and development, and compensation and retention.

For similarities, first, each firm has a systematic recruitment and selection procedure. They have specific criteria to recruit new employees. Second, firms adopt the 10/20/70 principle, where employee capabilities are expected to improve for 10% by learning internally within the firms, learning external with supply chain partners, and joining international training; 20% by learning from supervisor or coach feedback and monitoring, e.g., inviting professors from overseas to coach the project; and 70% by learning from project assignments or sharing of knowledge and skill with colleagues through project-based development, cross-functional teams, and employee orientation. Third, firms use KPI to evaluate performance of employees, where outstanding employees in terms of solving problems and promoting innovation are rewarded with prices and promoted to a higher position through career path development plans.

Across these three cases, firms also adopt other related HRM practices. First, GGC, Thai Oil, and SCG Chemicals adopt the STAR, SPEED-up, and hiring internal customers as the committee members, respectively, for the recruitment and selection process. Second, GGC uses the voluntary workforce and Idol System, whereas Thai Oil and SCG Chemicals create Project Innovation 101 and Idea Time Sessions, respectively, for the training and development of their human resources. Also, Thai Oil and SCG Chemicals recruit and collaborate with leading universities and research institutes by providing funding, scholarship, and sending researchers to local and overseas laboratories. Third, for retention and compensation, Thai Oil and SCG Chemicals provide master and Ph.D. scholarships to their employees for further studies with leading universities locally and internationally.

SRQ2: How and when firms adopt HRM practices to upgrade their technological capabilities, e.g., from non-formal to formal R&D firms?

The results from the case studies indicated that firms adopt various HRM practices, using internal efforts within the firm and external collaboration with supply chain partners, for upgrading their technological capabilities. There are four stages of technological capabilities (Arnold et al., 2000), and different stages require different types of HRM practices. The results from case studies show that, first, to move to the first stage of technology use and operation, firms need training from joint venture partners and suppliers for plant setup and operation. Second, for technological acquisition and assimilation, firms need specific recruitment packages and specific plans for training and development. Third, firms need cross-functional and project-based teams for innovation before they can upgrade from the second to the third stage of technology upgrading and reverse engineering. Lastly, to upgrade to R&D, firms need key R&D gurus, e.g., highly qualified personnel with master and Ph.D. degrees.

From the case studies, firms mainly upgrade their technological capabilities due to the following reasons. First, market expansion when firms need to set up new plants to expand their production capacity. From the case of SCG Chemical, the firm bought licenses from outside for plant set up and operation for the first plant. However, the SCG Chemical constructed the fourth plant by itself. Second, firms improve their technological capabilities when there are requirements from the outside. As presented earlier, Thai Oil is a joint venture company, where PTT is the major shareholder who owned 49.1%, so the Thai Oil needs to upgrade their technological capabilities when there are requirements from their major shareholder. Third, firms upgrade their technological capabilities when there is a good vision from the top management. For instance, the GGC and Thai Oil adopted the innovation strategies proposed by Dr. Pailin Chuchottaworn – the president and CEO of PTT Group. Similarly, Mr. Kan Trakulhoon – the president of SCG – set up an R&D lab to upgrade firm technological capabilities and promote innovation. Thus, each firm improves its technological capabilities from the fundamental stage of technology use and operation to the complex stage of R&D by using internal efforts and external collaboration.

6.2 A qualitative comparative analysis

Arnold et al. (2000) presented four stages of firm technological capabilities; however, we can see a more precise boundary of firm technological capabilities before and after an establishment of R&D. Similarly, Tsuji et al. (2018) and Intarakumnerd (2017) grouped firm technological capabilities as formal and non-formal R&D firms. Formal R&D firms are organisations with systematic and organised activities, e.g., have engaged in systematic innovation, have established an R&D department, or have allocated budgets for R&D intention, conducted to promote innovation and improve performance (OECD., 2015). Whereas, non-formal R&D is a process of collecting, processing, and applying information for problem-solving (Kleinknecht, 1987). This leads us to identify configurations of HRM practices and main mentors for promoting product innovation across different stages of technological capabilities, i.e., formal and non-formal R&D firms. The results from the qualitative comparative analysis help us to answer the **SRQ3** and **SRQ4**.

SRQ3: How firms combine internal and external HRM practices to promote innovation when they base in different stages of technological capabilities?

The results from the empirical study are presented in formal R&D firms and non-formal R&D firms. For formal R&D firms, the results indicate three main findings: (1) R&D personnel development help formal R&D firms to achieve high levels of product innovation, and if formal R&D firms do not have R&D personnel development, they need to collaborate with customers and suppliers; (2) QCCs do not help formal R&D firms to achieve high levels of product innovation, but it is somehow helpful after including supply chain collaboration; and (3) QCCs cause formal R&D firms to result in low levels of product innovation. Even with a presence of customer and supplier collaboration in addition to QCCs, formal R&D firms still result in low levels of product innovation if they do not adopt in-house training, engineer rotation, and R&D personnel development.

For non-formal R&D firms, the results also indicate three main findings: (1) there is no enough evidence to prove how important R&D personnel development is in achieving high levels of product innovation for non-formal R&D firms even with a presence or an absence of customer and supplier collaboration; (2) QCCs are somehow helpful for non-formal R&D firms as shown before and after including supply chain collaboration; (3) non-formal R&D firms result in low levels of product innovation if R&D personnel development is absent. Even with a presence or an absence of customer and supplier collaboration, non-formal R&D firms still result in low levels of product innovation if they just adopt in-house training with an absence of R&D personnel development

Across formal and non-formal R&D firms, first, firms should adopt R&D personnel development such that they can achieve more product innovation. If firms do not adopt R&D personnel development, they should at least collaborate with customers and suppliers to acquire knowledge for promoting innovation. Even some configurations in non-formal R&D firms do not show precise evidence on the significance of R&D personnel development for promoting product innovation, but firms mainly result in low levels of product innovation if they do not adopt R&D personnel development. Second, adopting only QCCs may cause firms to result in low levels in promoting product innovation, so firms should adopt other related practices, e.g., in-house training, engineer rotation, R&D personnel development, or collaborate with supply chain partners. These practices tend to be complementary to QCCs for promoting product innovation.

SRQ4: Who are the main mentors to manage human resources for innovative activities across different stages of firm technological capabilities?

The top management is the main mentor for promoting innovation in formal and non-formal R&D firms. This is also consistent with our case studies, where Dr. Pailin Chuchottaworn – the president and CEO of PTT Group – highly influences GGC and Thai Oil strategies. This is also found from the case of SCG Chemical, where Mr. Kan Trakulhoon is the main mentor for upgrading firm technological capabilities and promoting innovation. The results from the empirical study also indicated that the top management from formal R&D firms need to work with heads of R&D departments for promoting product innovation, whereas top management from non-formal R&D firms needs to work with managers of cross-functional teams. From the empirical result, there are no pathways that cause formal and non-formal R&D firms to result in low levels of product innovation. Thus, top management is the main mentors for promoting product innovation, where s/he mainly works with heads of R&D departments and managers of cross-functional teams for formal and non-formal R&D firms, respectively. Even the top management does not work directly with other related personnel, the top management should motivate them to join in knowledge sharing and co-creation because there is not configurations of main mentors that cause firms to result in low levels of product innovation.

6.3 Responses the MRQ

Firms mainly have different capabilities in human resources, financial capital, technological infrastructure, and experiences. These differences highly affect HRM practices for enhancing personnel capabilities, upgrading firm technological capabilities, and promoting innovation. To respond the **MRQ**: What types of HRM practices can be sources for upgrading firm technological capabilities in the Thai manufacturing context? how and why?, we synthesise the results from the qualitative analysis and qualitative comparative analysis. This helps us to indicate HRM practices needed for technology upgrading and innovation. Details to respond the **MRQ** are presented in Figure 6.1.

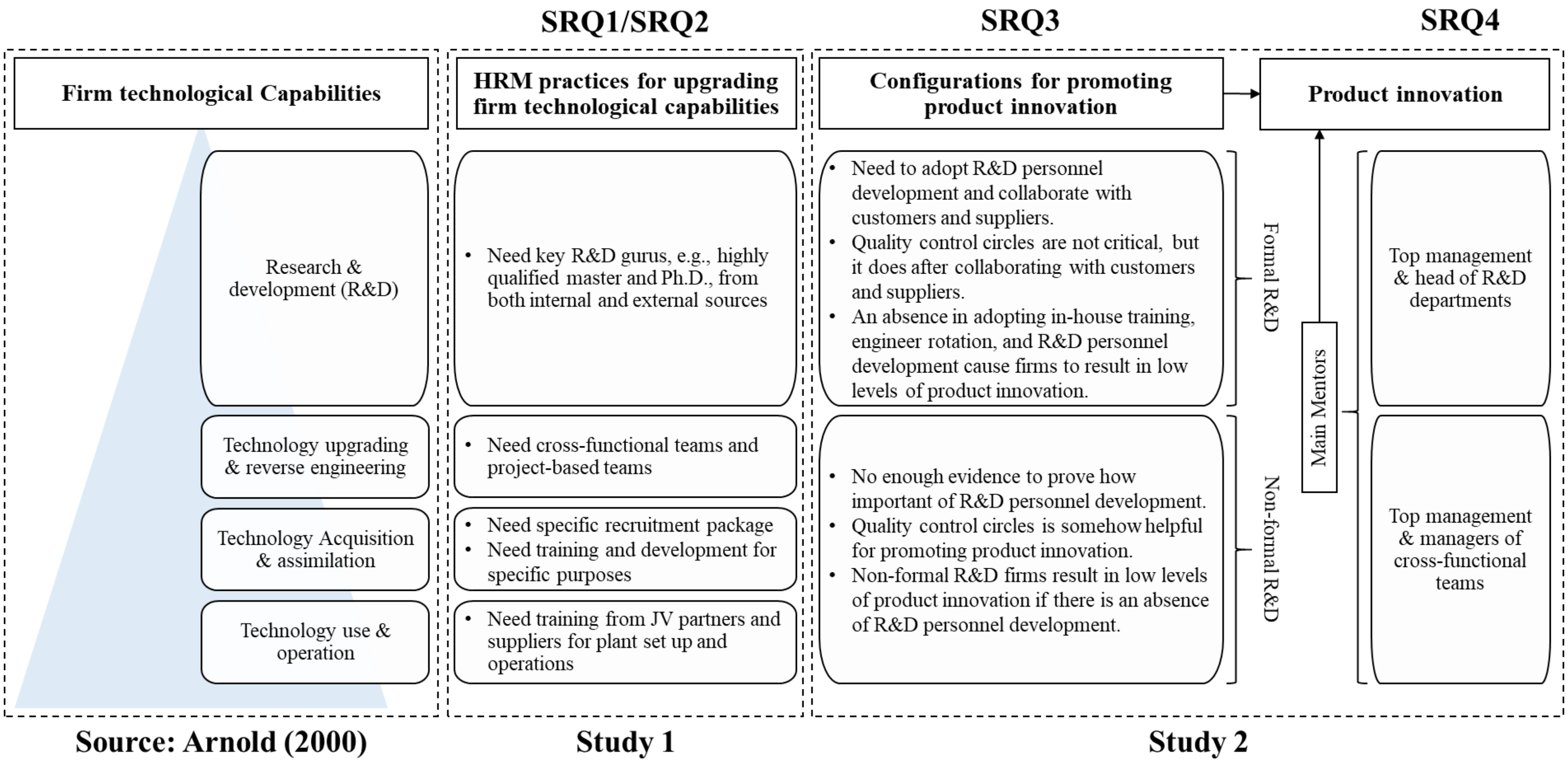

Figure 6.1: Responses to MRQ and SRQs (*Source*: Author)

6.4 Results comparison with less developing and developed countries

The finding tends to be more appropriate to the manufacturing firms in developing countries such as Thailand and Malaysia because firms in these countries have experienced massive knowledge transfer from foreign direct investors. After they have experienced technology use, operation, acquisition, and assimilation, the local firms tend to have higher internal capabilities as well as absorptive capacity. These capabilities allow them to develop their owned knowledge and technologies for technology upgrading and innovation. Currently firms in these countries are mainly based in Industry 3.0. With the governmental policies and their internal efforts, firms are upgrading toward Industry 4.0. They start to invest more on the human resources management to upgrade their technological capabilities. In addition, firms in these countries also allocated a portion of their sales for the purpose of R&D.

Comparing these results with other related studies in less developing countries, e.g., Vietnam and Laos, they share the similarities and differences. For the similarities, first, the top management (e.g., either founders or CEOs) mainly play a critical role as the main mentors for technology upgrading and innovation. S/he mainly initialises various innovative activities for other related personnel in their organisation, set up the organisational goal and strategies, and collaborate with supply chain partners to access new knowledge and skill (Intarakumnerd, 2017; Ueki, 2017). Second, the Japanese styles of HRM practices, e.g., teamwork, multi-skill development, 5S, QCCs, has been widely adopted by foreign affiliates of Japanese firms, based in Southeast Asia, and these styles of management are also diffused to local suppliers (Intarakumnerd, 2017). Thus, the local firms in less developing and developing countries in Southeast Asia mainly adopt QCCs and other related small group activities to improve their product and production process.

For the differences, first, firms in less developing countries tend to attract more foreign direct investors because firms can access low labour costs, huge markets in ASEAN and the world, and enormous natural resources. In addition, local people also have adequate capabilities to work with foreign firms, so these reduce the burden of foreign firms in enhancing and developing local employee capabilities. Compared to local firms in Thailand and Malaysia, local firms in less developing countries could be considered as newbies to the industry, where they are mainly based on Industry 2.0, and are in the process of upgrading toward Industry 3.0. Sources of knowledge and technologies of local firms still highly depend on the foreign direct investors. They are in the process of learning and acquisition to improve and enhance their internal capabilities and absorptive capacity. For example, the domestic electronics firms in Vietnam seem not to catch up with the development of the industry in the country; however, firms make an effort to link with local resources such as universities, business associations, and joining international trade fairs (Intarakumnerd, 2017).

Comparing the results with developed countries such as Japan, first, not every Japanese firm can adopt formal R&D firms like Fujitsu, Sharp, and Toshiba. Firms, especially micro, small, and medium enterprises (MSMEs) also adopt non-formal R&D for promoting innovation. From the field study of three Japanese SMEs, i.e., Dynic, Kyokko, and Maeda, Tsuji et al. (2017b) stated that only the first two firms have their own R&D centre, where Maeda does not due to the size of the firms. Hence, even firms, especially MSMEs, in the developed countries also promote innovation by adopting non-formal R&D practices because they have limited investment funds, lack R&D personnel, and are based in the stage of technology use and operation.

Second, QCCs and other related small group activities are considered as one of the key management styles, where the Japanese firms believed that participation, cooperation, and collaboration of every individual through QCCs strengthen the vigour and efficiency of business operations (Watanabe, 1991). QCCs bring benefits in various ways to Japanese firms, e.g., 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 organisational performance (Watanabe, 1991). Besides Japan, the QCCs also transferred through the foreign direct investment of Japanese firms to other countries in less developing and developing countries. For example, Toyota has adopted the QCCs, and when this firm expands its production plants to Thailand, it brought the QCCs. During its business operation, Toyota required local suppliers, e.g., Thai Summit, to adopt QCCs, where these practices are considered as one of the minimum criteria to be Toyota's suppliers.

Third, MSMEs in Japan normally have top management as the owner of the company, where the owner mainly has an engineering background with adequate knowledge, skill, and experiences to develop new products/services. S/he is the main mentor for promoting innovation in the early stage of business operation of venture or start-up firms (Tsuji et al., 2017b). When the firms are expanding in size and upgrading to formal R&D, their management styles tend to shift to middle-up-down and bottom-up management systems. This is because the Japanese firms believe that knowledge is created and co-created through socialisation, externalisation, combination, and internalisation in various environments at an individual, group, and organisation levels.

Thus, there are similarities and differences if we compare the results of this study with less developing countries, e.g., Laos and Vietnam, and developed countries, e.g., Japan. First, QCCs tend to be important in Japan to create new knowledge for promoting innovation and upgrading firm technological capabilities. However, it is less critical in developing and less developing countries due to culture differences and the limited capabilities of shop-floor employees. Second, top management is mostly the owner of the firms, and s/he is the main mentor for promoting innovation among less developing, developing, and developed countries when the firms are in the stage of non-formal R&D. When the firms are upgraded to formal R&D, firms in Japan tend to adopt the bottom-up management systems to create new knowledge, promote innovation, and upgrade firm technological capabilities. Whereas firms in developing and less developing countries tend to adopt the top-down and some changes to middle-up down management systems. Third, firms in developed countries highly rely on internal efforts to upgrade their capabilities to formal R&D, and these make them to achieve more innovation and grow faster than firms in developing and less developing countries.

CHAPTER 7
CONCLUSIONS

Overview: This chapter draws theoretical implications, practical implications, governmental recommendations, limitations, and direction for future research so that it could be used as a comprehensive guideline for practitioners, government agencies, and researchers.

7.1 Theoretical implication

This research is conducted by using mixed methods, which is the adoption of qualitative analysis and qualitative comparative analysis. The qualitative approach helps us to gain insight knowledge of human resource management (HRM) practices for technology upgrading and innovation. Knowledge from case studies is integrated with an intensive literature review for empirical fs/QCA. This method helps us to configure HRM practices and main mentors that help firms to achieve high levels and cause firms to result in low levels of product innovation for each stage of firm technological capabilities. From the case studies and empirical analysis, we would like to propose the value chain of HRM to upgrade firm technological capabilities in the context of manufacturing firms in Thailand, as presented in Figure 7.1.

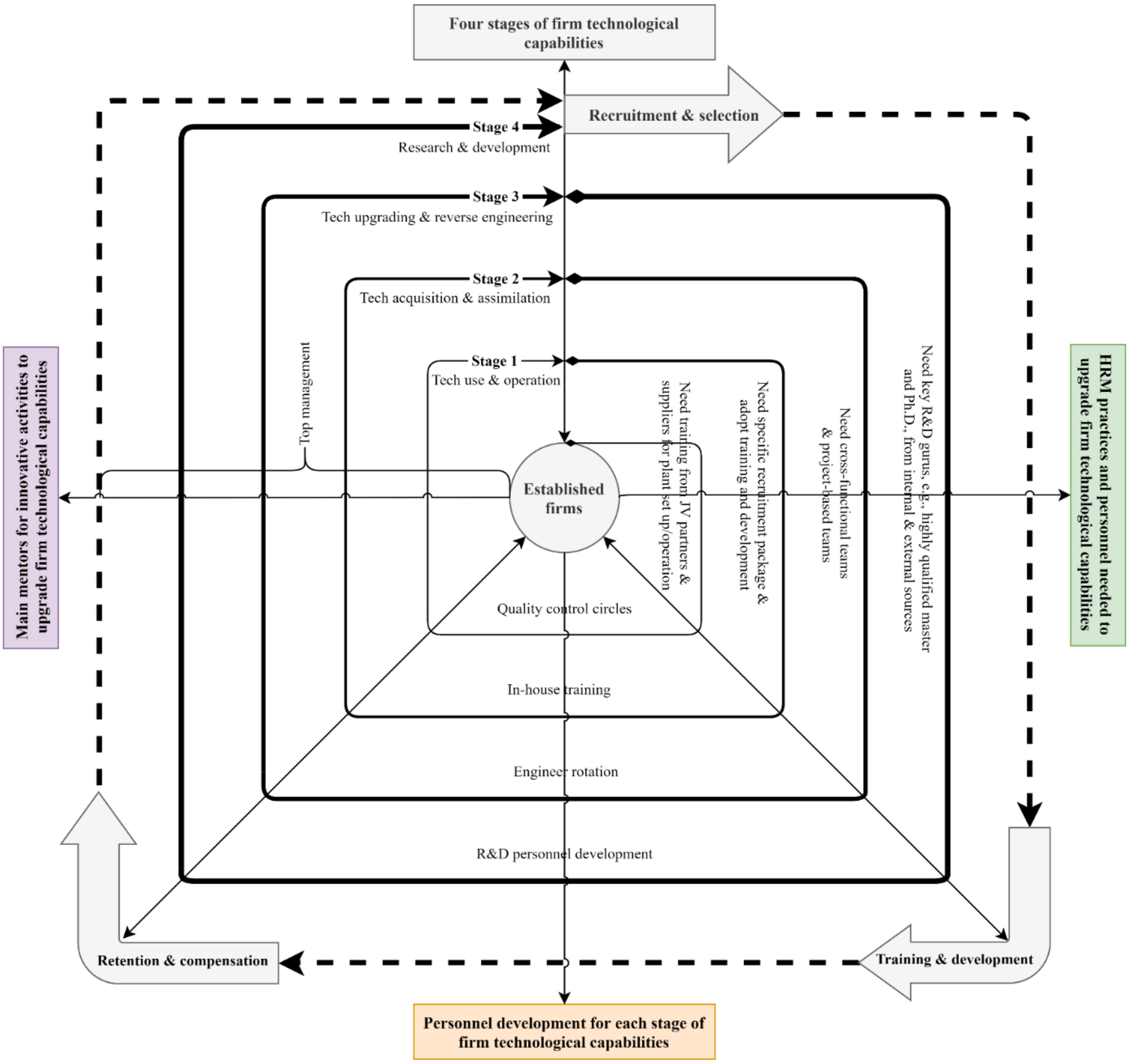

Figure 7.1: Value chains of HRM practices for upgrading firm technological capabilities (Source: Author)

The established firms need to upgrade their technological capabilities so that they can stay competitive in today's fast changing business environment. From the literature review, Arnold et al. (2000) defined four stages of firm technological capabilities, i.e., technology use and operation, technology acquisition and assimilation, technology upgrading and reverse engineering, and R&D, arranging them in ascending order of difficulties. In their studies, they defined the states of firms for each stage, but they do not identify coordination of internal and external HRM practices for upgrading firm technological capabilities from one stage to another.

Related to HRM practices, Fey, Björkman, and Pavlovskaya (2011) defined HRM practices as incentive systems, job security, employee training and career planning, decentralisation, internal promotion, and complaint resolution systems. Similarly, (1) Shipton et al. (2005) categorised HRM practices as recruitment and selection, induction, and appraisal and training; (2) Norasingh and Southammavong (2017) categorised HRM practices as recruiting and providing onsite training, working closely with communities, providing daily training at work place, outsourcing for some new projects that related to crafting product development, and experienced factory manager supervise craftsmen on new product development; and (3) Newell et al. (2009) categorised HRM practices of knowledge work as recruitment, selection and training, rewards provided to motivate good performance, and development of career tracks designed to keep employees working with the firms.

Even there are different types of HRM practices, they are not properly structured to be understood. Similar to innovation value chain theory (Hansen & Birkinshaw, 2007), we would like to consider HRM practices as a value chain. First, firms need to adopt recruitment and selection processes such that they can acquire highly qualified employees to work in the organisation. Second, firms need to adopt training and development processes to improve and enhance capabilities of current and newly recruited employees such that they can complete their job efficiently and effectively. Third, firms need to adopt compensation and retention processes to keep qualified employees to stay loyal with the organisation because fair incentives could bring the best potential from every employee and motivate them to stay longer with the organisation. Thus, firms need to align and implement HRM practices as a value chain such that they can enhance knowledge, skill, abilities, and commitment of employees for technology upgrading and innovation from one stage to another (Scarbrough, 2003).

From our case studies, there are similar and different adoption of HRM practices. For similarities, first, each firm has a systematic recruitment and selection procedure. They have specific criteria to recruit new employees. Second, firms adopt the 10/20/70 principle, where employee capabilities are expected to improve for 10% by learning internally within the firms, learning external with supply chain partners, and joining international training; 20% by learning from supervisor or coach feedback and monitoring, e.g., inviting professors from overseas to coach the project; and 70% by learning from project assignments or sharing of knowledge and skill with colleagues through project-based development, cross-functional team, and employee orientation. Third, firms use KPI to evaluate employee performance, where outstanding employees in terms of solving problems and promoting innovation are rewarded with prices and promoted to a higher position through career path development plans.

For the differences, first, GGC, Thai Oil, and SCG Chemicals adopt the STAR, SPEED-up, and hiring internal customers as the committee members, respectively, for the recruitment and selection processes. Second, GGC uses the voluntary workforce and Idol System, whereas Thai Oil and SCG Chemicals create Project Innovation 101 and Idea Time Sessions, respectively, for the training and development of their human resources. Also, Thai Oil and SCG Chemicals recruit and collaborate with leading universities and research institutes by providing funds, scholarships, and sending researchers to local and overseas laboratories. Third, for retention and compensation, Thai Oil and SCG Chemicals provide master and Ph.D. scholarships to their employees for further studies with leading universities locally and internationally.

Across the similarities and differences of HRM practices, the manufacturing firms in Thailand need different types of resources to upgrade firm technological capabilities from one stage to another. To move to the first stage of technology use and operation, firms need training from joining ventures with partners and suppliers for plant setup and operation. To move to the second stage of technology acquisition and assimilation, firms need specific recruitment packages and specific plans for training and development. Then firms need to adopt cross-functional teams and project-based teams to achieve the third stage of technology upgrading and reverse engineering. To upgrade to the last stage of R&D, firms need key R&D gurus, e.g., highly qualified persons with master and Ph.D. degrees, from internal and external sources. Even firms based in the last stage of R&D, they still need to innovate and keep improving their capabilities by adopting the cycle of recruitment and selection, training and development, and retention and compensation process.

HRM practices, i.e., recruitment and selection, training and development, and retention and compensation, need to be adopted as a value chain for technology upgrading and innovation, but not every firms is capable of adopting these practices to upgrade their technological capabilities because firms have different capabilities in human resources, financial capital, and organisational infrastructures. For example, firms do not always adopt recruitment and selection of new employees to upgrade their technological capabilities from one stage to another. They may just provide training and develop the capabilities of current employees. Similarly, the SMEs tend to pay less attention to retention and compensation processes because firms have limited financial capital and infrastructures. This problem causes firms difficulties in hiring highly qualified candidates and keeping qualified employees to stay longer with the firms. The large firms tend to have more specific retention and compensation program to attract and keep qualified employees to stay longer with the firms.

Using HRM practices as our theoretical foundation, the empirical study of this dissertation makes the contributions as follows. First, the literature mainly adopts conventional methods and generalises conclusions over sources of HRM practices for promoting innovation. For instances, Glaister et al. (2018) defined HRM practices as, i.e., training and development, recruitment and selection, workforce planning, and performance appraisal, and used them as causal conditions to study their effects on firm performance; and Zhang et al. (2016) studied relationships between HRM practices and innovation, then they identified whether innovation is a mechanism between HRM practices and firm performance. Results from these studies may not fully represent and explain what happens in the workplace, where various configurations of HRM practices are related differently in promoting product innovation. The results from this study, for instance, show that R&D personnel development help formal R&D firms to achieve high levels of product innovation, and if formal R&D firms do not adopt R&D personnel development, they need to collaborate with customers and suppliers as an alternative option such that they can promote product innovation. Therefore, the results from this study improve our understanding by providing various alternative sources for promoting product innovation.

Second, researchers highlighted various best HRM practices, but the best 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 top management entirely adopts those practices without understanding contexts of business operation, culture, norm and value of local employees (Newell et al., 2009). Jørgensen and Becker (2017) stated that there is no one best HRM practice for promoting innovation, and the best HRM practices should align with the context of business operation. For example, Gill and Wong (1998) highlighted five best practices of the Japanese management styles, i.e., lifetime employment, seniority systems, house unions, consensual decision making, and quality control circles (QCCs), and these practices help the Japanese firms to successfully manage, expand, and penetrate their organisations into global markets. Among these practices only house unions, consensual decision making, and QCCs are transferable to Singapore, but lifetime employment and seniority systems are problematic in adopting because of cultural differences (Gill & Wong, 1998). In the Thai manufacturing context, QCCs do not help formal R&D firms to achieve high levels of product innovation, but it is somehow helpful after including supply chain collaboration. In addition, QCCs are also helpful for non-formal R&D firms even before and after including supply chain collaboration. Hence, this study highlights that finding and adopting the best fit of HRM practices in accordance with our context are more critical than adopting the best practices from outside context (Newell et al., 2009).

Third, the literature review acknowledges the significance of top management for promoting product innovation in formal R&D firms (Binh & Linh, 2017) and non-formal R&D firms (Ueki, 2017); however, they do not sufficiently specify the co-mentors in promoting product innovation. Therefore, our finding contributes by appreciating the importance of top management for promoting product innovation, and s/he needs to work with heads of R&D departments and managers of cross-functional teams for formal and non-formal R&D firms, respectively.

Finally, no research papers have been found on the configurations of HRM practices that cause firms to result in low levels of product innovation. Hence, the results of this study found that QCCs cause formal R&D firms to result in low levels of product innovation. Even with a presence of customer and supplier collaboration in addition to QCCs, formal R&D firms still result in low levels of product innovation if they do not adopt in-house training, engineer rotation, and R&D personnel development. Similarly, the results on non-formal R&D firms indicate that firms may result in low levels of product innovation if they do not adopt R&D personnel development. Even with a presence or an absence of customer and supplier collaboration, non-formal R&D firms still result in low levels of product innovation if they do not adopt R&D personnel development. These results improve our understanding of not only sources that help firms to achieve high levels of product innovation but also sources that may cause firms to result in low levels of product innovation.

7.2 Practical implications

For the qualitative analysis, we would like to draw good corporate strategies for firm capabilities development as follows. First, the top management should play an important role in setting up business strategies so that the firms can upgrade technological capabilities step by step. Hence, firms are recommended to hire experienced CEOs and managers with technical knowledge in the area. Second, the human resource department needs to support firms in terms of HRM by setting up innovation strategies, specific recruitment and selection processes, more training and development programs, and clear retention and compensation packages to retain employees. Also, firms need to instil an innovation culture, provide training and development programs, and clear career path development for key personnel such that the firms' business strategies can be accomplished. Third, the firm needs to arrange training for its employees and create a knowledge-sharing environment for knowledge co-creation. Fourth, for long-term innovation development, the firms need to push an internal innovation culture. Every single person in the firm from the top management to the lowest position needs to be involved by sharing his/her logical concerns and thinking.

For the quantitative comparative analysis, firms mainly adopt HRM practices based on their capabilities, where large firms tend to have stronger capabilities to invest in formal R&D (Intarakumnerd, Chairatana, & Tangchitpiboon, 2002; Petsas & Giannikos, 2005) and possess innovative advantages over smaller firms in terms of heterogeneous R&D activities (Choi & Lee, 2017). Therefore, top management needs to realise their firm technological capabilities whether it is formal or non-formal R&D (Intarakumnerd, 2017; Tsuji et al., 2018), such that they can adopt appropriate HRM practices in accordance with firm technological capabilities to promote product innovation. The results from this study, for example, show that R&D personnel development helps formal R&D firms achieve product innovation, whereas QCCs 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, and QCCs somehow help non-formal R&D firms to achieve product innovation. In addition, the results also show that collaboration with customers and suppliers is complementary in helping firms to promote product innovation in formal R&D forms, but these collaborations seem to be less significant if they are non-formal R&D firms. Therefore, any type of HRM practice is beneficial in its ways to promote product innovation, as long as the top management is capable of identifying related complementary HRM practices.

From this study, firms in developing and less developing countries mainly have limited capabilities in human resources and financial capital. They rarely or cannot achieve radical innovation to upgrade their technological capabilities by themselves. They need to rely on external sources of knowledge, and more specifically knowledge, skill, and technologies from the upstream and downstream supply chain partner, e.g., customers and suppliers. There are different forms of collaboration that most firms adopt with their customers and suppliers. Among those forms, firms mainly collaborate with suppliers to set up plants and improve current systems and collaborate with customers to improve product packages and qualities to match with standard requirements (Hsieh et al., 2017). Thus, internal efforts alone are not enough, especially SMEs in less developing and developing countries, they need to collaborate at least with customers and suppliers to achieve new knowledge through knowledge transfer and spill over, promote innovation through knowledge exploration and risk sharing, and upgrading their capabilities through knowledge exploitation and formal R&D development.

7.3 Government recommendations

There is a big door for improvements that the government can assist locally-own firms. First, the government needs to set up experience-sharing workshops and encourage entrepreneurs to participate in international exhibitions. This helps to improve mindsets of local entrepreneurs on innovation development. Second, the government needs to set policies to subsidise training for upgrading capabilities of local firms, either by hiring foreign engineers and technicians from MNC firms or sending local engineers to learn abroad. These help for capacity building for SMEs and make local firms ready for knowledge transfer and knowledge co-creation. Third, motivation for mobilizing foreign experts, e.g., engineering, R&D personnel, or top executive management, is necessary because knowledge is hidden in these people. They are an agent of knowledge transfer. This can be achieved by attracting more foreign direct investment and encouraging local firms to join ventures or collaborate with multinational corporation firms. Fourth, the government needs to improve an educational standard such that the technical skill of employees, R&D personnel, and engineers are relevant to support innovation activities. Fifth, the government needs to support and commercialise R&D to push national innovation incrementally or vertically.

7.4 Limitations

There are four main limitations; first, the results may represent manufacturing firms in an emerging economy, e.g. Thailand and other countries in Southeast Asia, because firms these firms mainly have low internal capabilities, and they mainly adopt top-down management systems for promoting innovation. This may be different from developed nations, e.g., Japan, the US, or the EU, where firms mainly have high capabilities, and they may adopt the bottom-up or middle-up-down system for promoting innovation. Second, fs/QCA is used to identify configurations of causal conditions in achieving high levels or resulting in low levels of outcomes. These configurations are identified based on the provided causal conditions and outcomes. Thus, results in this study limit to internal HRM practices, supply chain collaboration, and main mentors presented in this research. Additional causal conditions may lead to variation in configurations for promoting product innovation. Third, firms may share the same configurations to achieve high levels and result in low levels of product innovation. These conflicts can be solved by making assumption on complex solutions to achieve intermediate and parsimonious solutions. However, this study presents only complex solutions, and we mainly make conclusions on conditions presented in every configuration to achieve high levels and result in low levels for each type of product innovation. Fourth, the raw coverage values may be low, especially in identifying the main mentors for promoting product innovation in non-formal R&D firms, so factors of causal conditions may need to be reduced based on knowledge from the qualitative approach, such that raw coverage values can be increased.

7.5 Directions for future studies

For further studies, first, this study can 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 a different perspective on the significance of internal HRM practices, supply chain collaboration, and main mentors 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 systems for promoting innovation. This is because different management systems lead firms to adopt different practices to create knowledge for promoting innovation. Besides, the manufacturing industry in an emerging economy, this study can be expanded to study practices for promoting product innovation in service and agricultural industry. Also, other types of innovation, e.g., process, technological, marketing, and position innovation, can be investigated because different practices in terms of internal HRM practices, supply chain collaboration, and main mentors may be required to achieve these innovations.

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APPENDICES

APPENDIX A

SEMI-STRUCTURED QUESTIONNAIRES FOR CASE ANALYSIS

Purpose: This section provides the semi-structured questionnaire, designed for in-depth case interview with the manufacturing firms in Thailand. Three firms, i.e., Global Green Chemicals Public Company Limited (GGC), Thai Oil Public Company Limited (Thai Oil), and Siam Cement Group Chemicals Company Limited (SCG Chemical), are purposely selected to include in this study because they experienced transition in upgrading their capabilities from the fundamental stage of technology use and operation to the complex stage of R&D. We promise to keep confidential for some information, suggested by the interviewees.

Part 1: Basic information

- Year of establishment
- Sales (US$, percentage of export/total sales)
- Employment (percentage of engineers and technical staff)
- Ownership (percentage of local and foreign ownership)
- Connection to global value chains (OEM/ODM/OBM)
- Business history, e.g., expansion of current businesses, and foreign investments.
- Innovation achievement, e.g., product/process

Part 2: HRM practices for technology upgrading

SRQ1: What types of HRM practices are needed to upgrade firm technological capabilities?

- From the firm's history, what are the internal and external mechanisms of HRM practices that firms adopted for technology upgrading and innovation?
    - Internal mechanisms
        - New staff recruitment: what qualification? how?
        - Training: which type, e.g., formal or on-the-job-training? how long? How often?
        - Personnel rotation: a common practice? who were rotated? how often?
        - Project-based management: a common practice? how to manage?
        - Cross-functional teams: a common practice? how to manage?
        - Reward systems to promote skill development and better performance: a common practice? What types, e.g., pay rise or promotion? How?
    - External mechanisms
        - Improving human resources through interacting with external partners, e.g., suppliers, customers, universities, or public research institutes.
        - Personnel exchanges: a common practice? who were exchanged? How long? How often?
        - Joint projects: a common practice? who were partners? What were the activities, e.g., joint R&D or joint design project? How were they managed?

    - External training: a common practice? By whom? How long? How often?
- What types of human resources needed for each stage of firm technological capabilities? How firms develop human resources and prepare them for technology use and operation, technology acquisition and assimilation, technology upgrading and reverse engineering, and R&D?
- Did firms have HRM systems for technology upgrading and innovation? If, yes, what types of HRM systems? Is HRM systems a part of or corresponding to the overall technology upgrading and innovation strategy? How?

SRQ2: How and when firms adopt HRM practices to upgrade their technological capabilities, e.g., from non-formal to formal R&D?

- How firms achieve technology upgrading and innovation when they do not have formal R&D units or R&D personnel allocated for R&D purpose?
- How firms combine internal resources with external resources for technology upgrading and innovation?
- If firms started to have formal R&D, describe the firm capability development process? why and how they moved from non-formal to formal R&D?

Part 3: Main mentors for technology upgrading and innovation

- Who was the main mentor for technology upgrading and innovation?
- Describe the education background and experiences of the main mentors?
- What was the rational for technology upgrading and innovation? Why?

Part 4: Outcomes of adopting HRM

- Did internal and external mechanisms of HRM practices add new skill/knowledge to the employees and result in increasing in overall technological/innovation capabilities of firms?

APPENDIX B

QUESTIONNAIRES FOR EMPIRICAL ANALYSIS

Purpose: This questionnaire was designed to investigate configurations of causal conditions, i.e., internal HRM practices, supply chain collaboration, and main mentors for promoting innovation, 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 results from this study provide a comprehensive guideline to the manufacturing firms in accordance with firm technological capabilities. The collected data will be kept confidentially and only use them for the purpose of research.

Part 1: Profile of an establishment

Please write your contact information for the person we should contact if there are any queries regarding the form

Company Name	
Address	
Title/Position	
Website	

Q1. When, how and where was your establishment founded and location of your establishment at present?

Q1.1. When and where was your company first established?		Year:
		Location:
Q1.2. Current Location of your establishment?	1. Province	
	2. City/Municipality	
	3. Industrial park	
Q1.3. What is the ownership structure of your establishment at present?	1. ☐ 100% Locally owned	
	2. ☐ 100% Foreign owned (MNC)	
	3. ☐ Joint Venture (JV)	

Q2 If your establishment is 100% foreign owned or joint venture, what are nationalities of the major FOREIGN investors? (Please mark (X) or tick ALL appropriate boxes)

Q2.1. Indonesian	1.☐ Yes	0.☐ No
Q2.2. Filipino	1.☐ Yes	0.☐ No
Q2.3. Thai	1.☐ Yes	0.☐ No
Q2.4. Vietnamese	1.☐ Yes	0.☐ No
Q2.5. Malaysian	1.☐ Yes	0.☐ No
Q2.6. Singaporean	1.☐ Yes	0.☐ No
Q2.7. Chinese	1.☐ Yes	0.☐ No
Q2.8. Japanese	1.☐ Yes	0.☐ No
Q2.9. South Korean	1.☐ Yes	0.☐ No
Q2.10. Taiwanese	1.☐ Yes	0.☐ No
Q2.11. American	1.☐ Yes	0.☐ No
Q2.12. European	1.☐ Yes	0.☐ No
Q2.13. Other, Specific		

Q3. Size of your establishment at present (Please tick ONE appropriate box)

Q3.1. Number of full-time employees (Persons)		
1.☐ 1-19 persons	5.☐ 200-299	9.☐ 1,000-1,499
2.☐ 20-49	6.☐ 300-399	10.☐ 1,500-1,999
3.☐ 50-99	7.☐ 400-499	11.☐ 2,000 or more
4.☐ 100-199	8.☐ 500-999	
Q3.2. Total Assets (US$)		

1. ☐ Less than 10,000 2. ☐ 10,000-24,999 3. ☐ 25,000-49,999 4. ☐ 50,000-74,999	5. ☐ 75,000-99,999 6. ☐ 100,000-499,999 7. ☐ 500,000-999,999 8. ☐ 1 million-4.9 mil.	9. ☐ 5 mil. -9.9 mil. 10. ☐ 10 million or more
Q3.3. How much is the ratio between R&D expenditure and sales at present?	0 ☐ No Expenditure 1 ☐ Less than 0.5%	2 ☐ 0.5-0.99% 3 ☐ 1% or more

Q4. Main business activity of your establishment? (Please tick all appropriate box)

1. ☐ Food, beverages, tobacco	11. ☐ Non-ferrous metals
2. ☐ Textiles	12. ☐ Metal products
3. ☐ Apparel, leather	13. ☐ Machinery, equipment, tools
4. ☐ Footwear	14. ☐ Computers & computer parts
5. ☐ Wood, wood products	15. ☐ Other electronics & components
6. ☐ Paper, paper products, printing	16. ☐ Precision instruments
7. ☐ Chemicals, chemical products	17. ☐ Automobile, auto parts
8. ☐ Plastic, rubber products	18. ☐ Transportation equipment/parts
9. ☐ Other non-metallic mineral products	19. ☐ Handicraft
10. ☐ Iron, steel	20. ☐ Other, specify:

Q5. Types of product manufacturing

Q5.1. What does your establishment mainly produce? (Please tick ONE appropriate box)	1. ☐ Raw materials 2. ☐ Raw material processing 3. ☐ Components and parts 4. ☐ Final products
Q5.2. Does your establishment manufacture products according to your own design or drawings?	0. ☐ No 1. ☐ Yes
Q5.3. How often new products are released in your firm (product life cycle)?	1. ☐ Custom-made 2. ☐ Every 6 months or less 3. ☐ Every 7-11 months 4. ☐ Every 1-2 years 5. ☐ Every 3-4 years 6. ☐ Every 5-6 years 7. ☐ Every 7 years or more

Part 2: Achievements for upgrading product and process innovation

Q6. Have you tried to introduce a new product in the last 2 years?	1. ☐ Yes (=> Go to Q6.1) 0. ☐ No (=> Go to Q7)
Q6.1. Redesigning packaging or significantly changing appearance design.	0. ☐ Not tried yet 1. ☐ Tried 2. ☐ Achieved
Q6.2. Significantly improving current products.	0. ☐ Not tried yet 1. ☐ Tried 2. ☐ Achieved
Q6.3. Producing new products based on existing technologies.	0. ☐ Not tried yet 1. ☐ Tried 2. ☐ Achieved
Q6.4. Producing new products based on new technologies.	0. ☐ Not tried yet 1. ☐ Tried 2. ☐ Achieved

Q7. Has your establishment improved the followings process in the last 2 years?

Q7.1. Reducing defects during a manufacturing process	0. ☐ No	1. ☐ Little 2. ☐ Somewhat 3. ☐ much

Q7.2. Reducing labour-input (person-hour)	0.☐ No	1.☐ Little 2.☐ Somewhat 3.☐ much
Q7.3. Reducing lead time to introduce a new product	0.☐ No	1.☐ Little 2.☐ Somewhat 3.☐ much
Q7.4. Reducing unscheduled line stops	0.☐ No	1.☐ Little 2.☐ Somewhat 3.☐ much
Q7.5. Reducing workers' injuries	0.☐ No	1.☐ Little 2.☐ Somewhat 3.☐ much
Q7.6. Reducing plant accidents	0.☐ No	1.☐ Little 2.☐ Somewhat 3.☐ much
Q7.7. Reducing delivery delays	0.☐ No	1.☐ Little 2.☐ Somewhat 3.☐ much
Q7.8. Reducing dispersion in product quality.	0.☐ No	1.☐ Little 2.☐ Somewhat 3.☐ much
Q7.9. Reducing time for a changeover of a production line	0.☐ No	1.☐ Little 2.☐ Somewhat 3.☐ much
Q7.10. Reducing plant maintenance costs	0.☐ No	1.☐ Little 2.☐ Somewhat 3.☐ much

Part 3: Human resource management practices

Q8. In-house training

Q8.1. Does your indigenous employee develop training course without help from outside?	1.☐ Yes 0.☐ No
Q8.2. Does your indigenous employee develop training materials without help from outside?	1.☐ Yes 0.☐ No
Q8.3. Does your indigenous employee serve as a trainer and lecturer for your training course?	1.☐ Yes 0.☐ No
Q8.4. Does your establishment have an in-house training facility/centre?	1.☐ Yes 0.☐ No

Q9. Engineer rotation

Q9.1. Does your establishment have a rotational program for your engineers, in which they rotate through various roles within a department of your establishment?	1.☐ Yes 0.☐ No
Q9.2. Does your establishment have a rotational program for your engineers, in which they rotate through various departments within your establishment?	1.☐ Yes 0.☐ No
Q9.3. Does your establishment have a career path program for engineers to develop leaders of innovative activities?	1.☐ Yes 0.☐ No
Q9.4. Does your establishment have an external secondment program that gives your engineers opportunities to work at other establishments?	1.☐ Yes 0.☐ No

Q10. R&D personnel development

Q10.1. Does your establishment conduct small group activities among R&D personnel?	1.☐ Yes 0.☐ No
Q10.2. Does your R&D personnel have regular meetings to discuss their common problems or solution?	1.☐ Yes 0.☐ No
Q10.3. Does your establishment develop personnel in charge of R&D?	1.☐ Yes 0.☐ No

Q11. Quality control circles (QCCs)

Q11.1. Does your establishment have systems to disseminate successful experiences of QCCs across your establishment?	1.☐ Yes 0.☐ No
Q11.2. Does your establishment have systems to learn successful experiences of QCCs from your customers/suppliers?	1.☐ Yes 0.☐ No

Part 4: Supply chain collaboration

Q12. Customer collaboration

Q12.1. Does the main customer dispatch personnel to your establishment?	1.☐ Yes 0.☐ No
Q12.2. Does your establishment provide any training to the main customer?	1.☐ Yes 0.☐ No
Q12.3. Does your establishment receive any training from the main customer?	1.☐ Yes 0.☐ No
Q12.4. Does your establishment design a new product or service with the main customer?	1.☐ Yes 0.☐ No
Q12.5. Does engineers of your establishment obtain new technologies and knowledge through training at/learning from the main customer?	1.☐ Yes 0.☐ No
Q12.6. Does your establishment ask advice from or cooperate with foreign-owned (MNC/JV) customers?	1.☐ Yes 0.☐ No
Q12.7. Does engineers of your establishment communicate directly with engineers of your customers?	1.☐ Yes 0.☐ No

Q13. Supplier collaboration

Q13.1. Does the main supplier dispatch personnel to your establishment?	1.☐ Yes 0.☐ No
Q13.2. Does your establishment provide any training to the main supplier?	1.☐ Yes 0.☐ No
Q13.3. Does your establishment receive any training from the main supplier?	1.☐ Yes 0.☐ No
Q13.4. Does your establishment design a new product or service with the main supplier?	1.☐ Yes 0.☐ No
Q13.5. Does engineers of your establishment obtain new technologies and knowledge through training at/learning from the main supplier?	1.☐ Yes 0.☐ No
Q13.6. Does your establishment ask advice from or cooperate with foreign-owned (MNC/JV) suppliers?	1.☐ Yes 0.☐ No
Q13.7. Does engineers of your establishment communicate directly with engineers of your suppliers?	1.☐ Yes 0.☐ No

Part 5: Main mentors for promoting innovation

Q14. Backgrounds of your establishment's top management (CEO)

Q14.1. Country origin of top management	1.☐ Local 2.☐ Foreign country (Specify:)
Q14.2. Ages of your establishment's top management	1.☐20s 2.☐30s 3.☐40s 4.☐50s 5.☐ 60s 6.☐70s up
Q14.3. What is the educational record of your top management?	1.☐ Bachelor 2.☐ Master 3.☐ Ph.D. 4.☐ Other
Q14.4. Was or Is the top management an engineer?	1.☐ Yes 0.☐ No
Q14.5. Is the top management founder or from founder's family?	1.☐ Founder 2.☐ Founder's family 0.☐ No

Q14.6. Does the top management have experiences working for MNCs/JVs?	1.☐ Yes 0.☐ No

Q15. Who are the main mentors for promoting innovation?

Q15.1. Top management	1.☐ Yes 0.☐ No
Q15.2. Heads of R&D departments	1.☐ Yes 0.☐ No
Q15.3. Engineers in R&D departments	1.☐ Yes 0.☐ No
Q15.4. Managers of cross-functional teams	1.☐ Yes 0.☐ No
Q15.5. Employees of cross-functional teams	1.☐ Yes 0.☐ No
Q15.6. Engineers in non-formal R&D departments	1.☐ Yes 0.☐ No
Q15.7. Production line leaders	1.☐ Yes 0.☐ No
Q15.8. Factory workers	1.☐ Yes 0.☐ No
Q15.9. Office workers	1.☐ Yes 0.☐ No

APPENDIX C
RESULTS ON COMPLEX, INTERMEDIATE, AND PARSIMONIOUS SOLUTIONS

Part 1: Configurations of internal HRM practices to achieve high levels and result in low levels for each type of product innovation in formal R&D firms

1.1. To achieve high levels in redesigning packaging or significantly changing appearance design. (pdi1)

****
TRUTH TABLE ANALYSIS
****
Model: *pdi1 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.810345

	raw coverage	unique coverage	consistency
	----------	----------	----------
*~it*pd*~qcc*	0.282944	0.127369	0.833766
*er*pd*~qcc*	0.227413	0.0718378	0.816456
solution coverage:	0.354782		
solution consistency:	0.796241		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.810345

	raw coverage	unique coverage	consistency
	----------	----------	----------
er~qcc*	0.227854	0.0722785	0.727145
*~it*pd*	0.361833	0.206258	0.819361
solution coverage:	0.434112		
solution consistency:	0.745083		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.810345
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
*~it*pd*~qcc*	0.282944	0.127369	0.833766
*er*pd*~qcc*	0.227413	0.0718378	0.816456
solution coverage:	0.354782		
solution consistency:	0.796241		

1.2. To result in low levels of redesigning packaging or significantly changing appearance design. (~ pdi1)

****
TRUTH TABLE ANALYSIS
****
Model: *~pdi1 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.936232		
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*	0.210973	0.210973	0.936232
solution coverage:	0.210973		
solution consistency:	0.936232		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.936232		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*~pd*qcc*	0.233834	0.0176356	0.711729
*~it*qcc*	0.258654	0.042456	0.623622
solution coverage:	0.27629		
solution consistency:	0.538853		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.936232		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*	0.210973	0.210973	0.936232
solution coverage:	0.210973		
solution consistency:	0.936232		

1.3. To achieve high levels in significantly improving current products. (pdi2)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *pdi2 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff: 2
consistency cutoff: 0.806122

	raw coverage	unique coverage	consistency
	----------	----------	----------
pd~qcc*	0.369128	0.213186	0.815881
it~er*pd*	0.241216	0.0852743	0.784339
solution coverage:	0.454402		
solution consistency:	0.802091		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff: 2
consistency cutoff: 0.806122

	raw coverage	unique coverage	consistency
	----------	----------	----------
pd~qcc*	0.369128	0.0777734	0.815881
*~er*pd*	0.388867	0.0975128	0.800163
solution coverage:	0.46664		
solution consistency:	0.789579		

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2
consistency cutoff: 0.806122
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
pd~qcc*	0.369128	0.213186	0.815881
it~er*pd*	0.241216	0.0852743	0.784339
solution coverage:	0.454402		
solution consistency:	0.802091		

1.4. To result in low levels of significantly improving current products. (~ pdi2)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
Model: ~pdi2 = f(it, er, pd, qcc)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff:        2
consistency cutoff:      0.936232
                         raw          unique
                         coverage     coverage     consistency
                         ----------   ----------   ----------
~it*~er*~pd*qcc          0.254933     0.254933     0.936232
solution coverage:       0.254933
solution consistency:    0.936232

--- PARSIMONIOUS SOLUTION ---
frequency cutoff:        2
consistency cutoff:      0.936232
                         raw          unique
                         coverage     coverage     consistency
                         ----------   ----------   ----------
~pd*qcc                  0.275454     0.0142068    0.693836
~it*qcc                  0.329913     0.0686662    0.658267
solution coverage:       0.34412
solution consistency:    0.555414

--- INTERMEDIATE SOLUTION ---
frequency cutoff:        2
consistency cutoff:      0.936232
Assumptions:
                         raw          unique
                         coverage     coverage     consistency
                         ----------   ----------   ----------
~it*~er*~pd*qcc          0.254933     0.254933     0.936232
solution coverage:       0.254933
solution consistency:    0.936232
```

1.5. To achieve high levels in producing new products based on existing technologies. (pdi3)

****
TRUTH TABLE ANALYSIS
****

Model: *pdi3 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.816092		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*~it*pd*~qcc*	0.309135	0.1375	0.835065
*er*pd*~qcc*	0.249519	0.0778846	0.821203
solution coverage:	0.387019		
solution consistency:	0.796241		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.816092		
	raw coverage	unique coverage	consistency
	----------	----------	----------
er~qcc*	0.249519	0.0778846	0.729958
*~it*pd*	0.384135	0.2125	0.797405
solution coverage:	0.462019		
solution consistency:	0.726929		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.816092		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
*~it*pd*~qcc*	0.309135	0.1375	0.835065
*er*pd*~qcc*	0.249519	0.0778846	0.821203
solution coverage:	0.387019		
solution consistency:	0.796241		

1.6. To result in low levels of producing new products based on existing technologies. (~ pdi3)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi3 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.936232

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*	0.187791	0.187791	0.936232
solution coverage:	0.187791		
solution consistency:	0.936232		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.936232

	raw coverage	unique coverage	consistency
	----------	----------	----------
*~pd*qcc*	0.261047	0.0686048	0.892644
*~it*qcc*	0.243023	0.0505815	0.658267
solution coverage:	0.311628		
solution consistency:	0.682803		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.936232
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*	0.187791	0.187791	0.936232
solution coverage:	0.187791		
solution consistency:	0.936232		

1.7. To achieve high levels in producing new products based on new technologies. (pdi4)

****
TRUTH TABLE ANALYSIS
****

Model: *pdi4 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.805556		
	raw coverage	unique coverage	consistency
	----------	----------	----------
it~er*pd*	0.282961	0.169878	0.716303
~it~er*~pd*qcc*	0.144016	0.0309331	0.823188
solution coverage:	0.313895		
solution consistency:	0.687014		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.805556		
	raw coverage	unique coverage	consistency
	----------	----------	----------
it~er*	0.363083	0.0973631	0.755274
*~pd*qcc*	0.160243	0	0.62823
*~er*qcc*	0.301724	0.00253549	0.661111
*~it*qcc*	0.225152	0.0167343	0.699212
solution coverage:	0.415821		
solution consistency:	0.600293		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.805556		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
it~er*pd*	0.282961	0.169878	0.716303
~it~er*~pd*qcc*	0.144016	0.0309331	0.823188
solution coverage:	0.313895		
solution consistency:	0.687014		

1.8. To result in low levels of producing new products based on new technologies. (~ pdi4)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi4 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.863768		
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*	0.16302	0.0590811	0.863768
*~it*er*pd*~qcc*	0.204595	0.100657	0.956522
solution coverage:	0.263676		
solution consistency:	0.882784		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.863768		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*~it*er*	0.230853	0.0213348	0.844
*~pd*qcc*	0.212254	0.0492342	0.771371
*~it*qcc*	0.293217	0.0339168	0.844095
solution coverage:	0.363786		
solution consistency:	0.790725		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.863768		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*	0.16302	0.0590811	0.863768
*~it*er*pd*~qcc*	0.204595	0.100657	0.956522
solution coverage:	0.263676		
solution consistency:	0.882784		

Part 2: Configurations of internal HRM practices to achieve high levels and result in low levels for each type of product innovation in non-formal R&D firms

2.1. To achieve high levels in redesigning packaging or significantly changing appearance design. (pdi1)

****
TRUTH TABLE ANALYSIS
****
Model*: pdi1 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.836648

	raw coverage	unique coverage	consistency
	----------	----------	----------
er~pd*~qcc*	0.163197	0.0695098	0.916981
~it~er*pd*	0.309939	0.204835	0.863424
*it*pd*qcc*	0.28274	0.168569	0.836147
solution coverage:	0.557085		
solution consistency:	0.828671		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.836648

	raw coverage	unique coverage	consistency
	----------	----------	----------
pd	0.558092	0.437206	0.761338
er~qcc*	0.190396	0.0695097	0.841246
solution coverage:	0.627602		
solution consistency:	0.767872		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.836648
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
er~pd*~qcc*	0.163197	0.0695098	0.916981
~it~er*pd*	0.309939	0.204835	0.863424
*it*pd*qcc*	0.28274	0.168569	0.836147
solution coverage:	0.557085		
solution consistency:	0.828671		

2.2. To result in low levels of redesigning packaging or significantly changing appearance design. (~ pdi1)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi1 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.807246		
	raw coverage	unique coverage	consistency
	----------	----------	----------
~er~pd*qcc*	0.341311	0.0790843	0.763679
it~pd*qcc*	0.372009	0.104579	0.820896
*~it*er*~pd*~qcc*	0.181582	0.0239334	0.832935
solution coverage:	0.475026		
solution consistency:	0.711613		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.807246		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*~it*er*	0.262747	0.0712799	0.712271
*~pd*qcc*	0.466702	0.275234	0.728085
solution coverage:	0.537982		
solution consistency:	0.669689		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.807246		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
~er~pd*qcc*	0.341311	0.0790843	0.763679
it~pd*qcc*	0.372009	0.104579	0.820896
*~it*er*~pd*~qcc*	0.181582	0.0239334	0.832935
solution coverage:	0.475026		
solution consistency:	0.711613		

2.3. To achieve high levels in significantly improving current products. (pdi2)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *pdi2 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.80817

	raw coverage	unique coverage	consistency
	----------	----------	----------
er~pd*~qcc*	0.184868	0.0704436	0.935849
~it~er*pd*	0.323146	0.202013	0.811038
it~er*qcc*	0.235557	0.0499441	0.784119
*it*pd*qcc*	0.319791	0.13716	0.852036
solution coverage:	0.652628		
solution consistency:	0.785906		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.80817

	raw coverage	unique coverage	consistency
	----------	----------	----------
pd	0.590384	0.381289	0.725607
er~qcc*	0.21394	0.0704436	0.851632
it~er*qcc*	0.235557	0.0499441	0.784119
solution coverage:	0.721207		
solution consistency:	0.727443		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.80817
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
er~pd*~qcc*	0.184868	0.0704436	0.935849
~it~er*pd*	0.323146	0.202013	0.811038
it~er*qcc*	0.235557	0.0499441	0.784119
*it*pd*qcc*	0.319791	0.13716	0.852036
solution coverage:	0.652628		
solution consistency:	0.785906		

2.4. To result in low levels of significantly improving current products. (~ pdi2)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *~pdi2 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.832935

	raw coverage	unique coverage	consistency
	----------	----------	----------
~er~pd*qcc*	0.329274	0.0829951	0.849825
it~pd*qcc*	0.345061	0.0942716	0.878301
*~it*er*~pd*~qcc*	0.15742	0.0207488	0.832935
solution coverage:	0.448805		
solution consistency:	0.775526		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.832935

	raw coverage	unique coverage	consistency
	----------	----------	----------
*~it*er*	0.251692	0.0802887	0.787024
*~pd*qcc*	0.439333	0.26793	0.790584
solution coverage:	0.519621		
solution consistency:	0.746114		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.832935
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
~er~pd*qcc*	0.329274	0.0829951	0.849825
it~pd*qcc*	0.345061	0.0942716	0.878301
*~it*er*~pd*~qcc*	0.15742	0.0207488	0.832935
solution coverage:	0.448805		
solution consistency:	0.775526		

2.5. To achieve high levels in producing new products based on existing technologies. (pdi3)

****
TRUTH TABLE ANALYSIS
****
Model: *pdi3 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.862216		
	raw coverage	unique coverage	consistency
	----------	----------	----------
er~pd*~qcc*	0.181618	0.0790441	0.932076
~it~er*pd*	0.328309	0.228676	0.83536
*it*er*pd*qcc*	0.251838	0.142279	0.900131
solution coverage:	0.559559		
solution consistency:	0.840884		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.862216		
	raw coverage	unique coverage	consistency
	----------	----------	----------
er~qcc*	0.208824	0.079044	0.84273
*~it*pd*	0.3625	0.21875	0.767315
*er*pd*	0.282353	0.11875	0.755162
solution coverage:	0.580147		
solution consistency:	0.763795		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.862216		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
er~pd*~qcc*	0.181618	0.0790441	0.932076
~it~er*pd*	0.328309	0.228676	0.83536
*it*er*pd*qcc*	0.251838	0.142279	0.900131
solution coverage:	0.559559		
solution consistency:	0.840884		

2.6. To result in low levels of producing new products based on existing technologies. (~ pdi3)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi3 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.832935		
	raw coverage	unique coverage	consistency
	----------	----------	----------
~er~pd*qcc*	0.321101	0.0862387	0.814901
it~er*qcc*	0.306422	0.0715596	0.828784
*~it*er*~pd*~qcc*	0.160092	0.0256882	0.832935
solution coverage:	0.418349		
solution consistency:	0.742671		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.832935		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*~it*er*	0.250917	0.0866974	0.771509
~er~pd*qcc*	0.321101	0.0862387	0.814901
it~er*qcc*	0.306422	0.0715596	0.828784
solution coverage:	0.479358		
solution consistency:	0.728731		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.832935		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
~er~pd*qcc*	0.321101	0.0862387	0.814901
it~er*qcc*	0.306422	0.0715596	0.828784
*~it*er*~pd*~qcc*	0.160092	0.0256882	0.832935
solution coverage:	0.418349		
solution consistency:	0.742671		

2.7. To achieve high levels in producing new products based on new technologies. (pdi4)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *pdi4 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.817051		
	raw coverage	unique coverage	consistency
	----------	----------	----------
er~pd*~qcc*	0.199043	0.0833665	0.941509
it~er*qcc*	0.256083	0.140407	0.796526
solution coverage:	0.33945		
solution consistency:	0.823814		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.817051		
	raw coverage	unique coverage	consistency
	----------	----------	----------
er~qcc*	0.237734	0.119266	0.884273
it~er*qcc*	0.256083	0.137615	0.796526
solution coverage:	0.375349		
solution consistency:	0.804274		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.817051		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
er~pd*~qcc*	0.199043	0.0833665	0.941509
it~er*qcc*	0.256083	0.140407	0.796526
solution coverage:	0.33945		
solution consistency:	0.823814		

2.8. To result in low levels of producing new products based on new technologies. (~ pdi4)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *~pdi4 = f(it, er, pd, qcc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.832935

	raw coverage	unique coverage	consistency
	----------	----------	----------
~er~pd*qcc*	0.288341	0.0601755	0.80326
it~pd*qcc*	0.307146	0.0748015	0.843858
*~it*er*~pd*~qcc*	0.145842	0.0192227	0.832935
solution coverage:	0.386544		
solution consistency:	0.720967		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.832935

	raw coverage	unique coverage	consistency
	----------	----------	----------
*~it*er*	0.212286	0.0534893	0.716502
*~pd*qcc*	0.38947	0.230673	0.756494
solution coverage:	0.442959		
solution consistency:	0.686529		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.832935
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
~er~pd*qcc*	0.288341	0.0601755	0.80326
it~pd*qcc*	0.307146	0.0748015	0.843858
*~it*er*~pd*~qcc*	0.145842	0.0192227	0.832935
solution coverage:	0.386544		
solution consistency:	0.720967		

Part 3: Configurations of internal HRM practices and supply chain collaboration to achieve high levels and result in low levels for each type of product innovation in formal R&D firms

3.1. To achieve high levels in redesigning packaging or significantly changing appearance design. (pdi1)

****
TRUTH TABLE ANALYSIS
****

Model: *pdi1 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey
--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.807439		
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*pd*~qcc*~cc*~sc*	0.241075	0.12208	0.883683
~it~er*~pd*~qcc*cc*sc*	0.123843	0.0277655	0.843844
it~er*pd*qcc*~cc*~sc*	0.162627	0.047598	0.807439
*it*er*pd*~qcc*~cc*sc*	0.154694	0.0356985	0.918848
solution coverage:	0.368004		
solution consistency:	0.809893		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.807439		
	raw coverage	unique coverage	consistency
	----------	----------	----------
pd~cc*	0.428383	0.255179	0.799342
*~qcc*sc*	0.261349	0.0881446	0.695193
solution coverage:	0.516527		
solution consistency:	0.741303		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.807439		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*pd*~qcc*~cc*~sc*	0.241075	0.12208	0.883683
~it~er*~pd*~qcc*cc*sc*	0.123843	0.0277655	0.843844
it~er*pd*qcc*~cc*~sc*	0.162627	0.047598	0.807439
*it*er*pd*~qcc*~cc*sc*	0.154694	0.0356985	0.918848
solution coverage:	0.368004		
solution consistency:	0.809893		

3.2. To result in low levels of redesigning packaging or significantly changing appearance design. (~ pdi1)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *~pdi1 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	1		
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*cc*sc*	0.192031	0.192031	1
solution coverage:	0.192031		
solution consistency:	1		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	1		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*~pd*qcc*	0.233834	0.00522536	0.711729
*~it*qcc*	0.258654	0	0.623622
*~er*qcc*cc*	0.321359	0.0280862	0.778481
*~er*qcc*sc*	0.273677	0	0.746881
solution coverage:	0.348792		
solution consistency:	0.562698		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	1		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*cc*sc*	0.192031	0.192031	1
solution coverage:	0.192031		
solution consistency:	1		

3.3. To achieve high levels in significantly improving current products. (pdi2)

****
TRUTH TABLE ANALYSIS
****
Model: *pdi2 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.910284		
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*pd*~qcc*~cc*~sc*	0.236084	0.117252	0.966074
~it~er*~pd*~qcc*cc*sc*	0.131465	0.0355309	1
it~er*pd*qcc*~cc*~sc*	0.164232	0.0568495	0.910284
*it*er*pd*~qcc*~cc*sc*	0.150809	0.0398736	1
solution coverage:	0.38255		
solution consistency:	0.939864		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.910284		
	raw coverage	unique coverage	consistency
	----------	----------	----------
pd~cc*	0.4394	0.256218	0.915296
*~qcc*sc*	0.286222	0.10304	0.849941
solution coverage:	0.54244		
solution consistency:	0.86907		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.910284		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*pd*~qcc*~cc*~sc*	0.236084	0.117252	0.966074
~it~er*~pd*~qcc*cc*sc*	0.131465	0.0355309	1
it~er*pd*qcc*~cc*~sc*	0.164232	0.0568495	0.910284
*it*er*pd*~qcc*~cc*sc*	0.150809	0.0398736	1
solution coverage:	0.38255		
solution consistency:	0.939864		

3.4. To result in low levels of significantly improving current products. (~ pdi2)

****
TRUTH TABLE ANALYSIS
****
Model: *~pdi2 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	1		
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*cc*sc*	0.232044	0.232044	1
solution coverage:	0.232044		
solution consistency:	1		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	1		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*~pd*qcc*	0.275454	0.00710341	0.693836
*~it*qcc*	0.329913	0.0173638	0.658267
*~er*qcc*cc*	0.348856	0.0307814	0.699367
*~er*qcc*sc*	0.301499	0 0.680927	
solution coverage:	0.400158		
solution consistency:	0.534247		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	1		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*cc*sc*	0.232044	0.232044	1
solution coverage:	0.232044		
solution consistency:	1		

3.5. To achieve high levels in producing new products based on existing technologies. (pdi3)

****
TRUTH TABLE ANALYSIS
****

Model: *pdi3 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.861066

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*pd*~qcc*~cc*~sc*	0.25625	0.123077	0.861066
~it~er*~pd*~qcc*cc*sc*	0.160096	0.0432692	1
*it*er*pd*~qcc*~cc*sc*	0.170192	0.0557692	0.926701
solution coverage:	0.355289		
solution consistency:	0.873522		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.861066

	raw coverage	unique coverage	consistency
	----------	----------	----------
pd~qcc*	0.391346	0.15	0.710297
*~qcc*sc*	0.308173	0.0668269	0.751465
solution coverage:	0.458173		
solution consistency:	0.703321		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.861066
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*pd*~qcc*~cc*~sc*	0.25625	0.123077	0.861066
~it~er*~pd*~qcc*cc*sc*	0.160096	0.0432692	1
*it*er*pd*~qcc*~cc*sc*	0.170192	0.0557692	0.926701
solution coverage:	0.355289		
solution consistency:	0.873522		

3.6. To result in low levels of producing new products based on existing technologies. (~ pdi3)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi3 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*cc*sc*	0.17093	0.17093	1
solution coverage:	0.17093		
solution consistency:	1		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
*~pd*qcc*	0.261047	0.0511628	0.892644
*~it*qcc*	0.243023	0	0.658267
*~er*qcc*cc*	0.281395	0.0284884	0.765823
*~er*qcc*sc*	0.225581	0	0.691622
solution coverage:	0.352326		
solution consistency:	0.638567		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*qcc*cc*sc*	0.17093	0.17093	1
solution coverage:	0.17093		
solution consistency:	1		

3.7. To achieve high levels in producing new products based on new technologies. (pdi4)

****
TRUTH TABLE ANALYSIS
****
Model: *pdi4 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.807439

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*cc*sc*	0.18712	0.0887424	0.838636
it~er*pd*qcc*~cc*~sc*	0.18712	0.0410751	0.807439
*it*er*pd*~qcc*~cc*sc*	0.181542	0.0522313	0.937173
*it*er*pd*qcc*cc*sc*	0.408722	0.27789	0.81332
solution coverage:	0.605984		
solution consistency:	0.780536		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.807439

	raw coverage	unique coverage	consistency
	----------	----------	----------
it	0.745436	0.131339	0.671233
sc	0.706389	0.0922921	0.742933
solution coverage:	0.837728		
solution consistency:	0.650906		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.807439
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*cc*sc*	0.18712	0.0887424	0.838636
it~er*pd*qcc*~cc*~sc*	0.18712	0.0410751	0.807439
*it*er*pd*~qcc*~cc*sc*	0.181542	0.0522313	0.937173
*it*er*pd*qcc*cc*sc*	0.408722	0.27789	0.81332
solution coverage:	0.605984		
solution consistency:	0.780536		

3.8. To result in low levels of producing new products based on new technologies. (~ pdi4)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi4 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.811816

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*~qcc*~cc*~sc*	0.287746	0.183808	0.862295
it~er*pd*qcc*~cc*~sc*	0.202954	0.0951859	0.811816
~it~er*~pd*qcc*cc*sc*	0.157549	0.0514224	0.979592
solution coverage:	0.438184		
solution consistency:	0.819857		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.811816

	raw coverage	unique coverage	consistency
	----------	----------	----------
*~er*qcc*	0.360503	0.216083	0.732222
~pd~sc*	0.397703	0.0421225	0.805987
~pd~cc*	0.349016	0	0.762246
solution coverage:	0.614333		
solution consistency:	0.735911		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.811816
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*~pd*~qcc*~cc*~sc*	0.287746	0.183808	0.862295
it~er*pd*qcc*~cc*~sc*	0.202954	0.0951859	0.811816
~it~er*~pd*qcc*cc*sc*	0.157549	0.0514224	0.979592
solution coverage:	0.438184		
solution consistency:	0.819857		

Part 4: Configurations of internal HRM practices and supply chain collaboration to achieve high levels and result in low levels for each type of product innovation in non-formal R&D firms

4.1. To achieve high levels in redesigning packaging or significantly changing appearance design. (pdi1)

****
TRUTH TABLE ANALYSIS
****

Model: *pdi1 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey
--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.85103		
	raw coverage	unique coverage	consistency
	----------	----------	----------
it~pd*~qcc*~cc*~sc*	0.225319	0.0883142	0.872562
~it~er*pd*~cc*~sc*	0.25319	0.168569	0.889151
*it*er*~pd*~cc*~sc*	0.165883	0.0231699	0.940952
*it*er*pd*qcc*cc*sc*	0.189725	0.0960375	0.861281
solution coverage:	0.521155		
solution consistency:	0.853685		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.85103		
	raw coverage	unique coverage	consistency
	----------	----------	----------
pd	0.558092	0.376427	0.761338
it~sc*	0.322028	0.00738746	0.845679
it~cc*	0.367025	0.013096	0.826153
solution coverage:	0.75957		
solution consistency:	0.77175		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.85103		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
it~pd*~qcc*~cc*~sc*	0.225319	0.0883142	0.872562
~it~er*pd*~cc*~sc*	0.25319	0.168569	0.889151
*it*er*~pd*~cc*~sc*	0.165883	0.0231699	0.940952
*it*er*pd*qcc*cc*sc*	0.189725	0.0960375	0.861281
solution coverage:	0.521155		
solution consistency:	0.853685		

4.2. To result in low levels of redesigning packaging or significantly changing appearance design. (~ pdi1)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi1 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff: 2
consistency cutoff: 0.840506

	raw coverage	unique coverage	consistency
	----------	----------	----------
it~pd*qcc*cc*sc*	0.340271	0.191468	0.925035
*it*er*~pd*qcc*~cc*~sc*	0.172737	0.0239335	0.840506
solution coverage:	0.364204		
solution consistency:	0.876095		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff: 2
consistency cutoff: 0.840506

	raw coverage	unique coverage	consistency
	----------	----------	----------
*~pd*qcc*	0.466702	0.466702	0.728085
solution coverage:	0.466702		
solution consistency:	0.728085		

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2
consistency cutoff: 0.840506
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
it~pd*qcc*cc*sc*	0.340271	0.191468	0.925035
*it*er*~pd*qcc*~cc*~sc*	0.172737	0.0239335	0.840506
solution coverage:	0.364204		
solution consistency:	0.876095		

4.3. To achieve high levels in significantly improving current products. (pdi2)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *pdi2 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.800898		
	raw coverage	unique coverage	consistency
	----------	----------	----------
~er~pd*~qcc*~cc*~sc*	0.327618	0.163623	0.741147
~it~er*pd*~cc*~sc*	0.265747	0.139396	0.840802
*it*er*~pd*~cc*~sc*	0.181141	0.0290719	0.925714
it~er*~pd*qcc*cc*sc*	0.144614	0.0290719	0.836206
*it*er*pd*qcc*cc*sc*	0.21804	0.102497	0.891768
solution coverage:	0.662318		
solution consistency:	0.745386		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.800898		
	raw coverage	unique coverage	consistency
	----------	----------	----------
~er	0.746925	0.0134178	0.614913
pd	0.590384	0.0942974	0.725607
~sc	0.654491	0.00782704	0.699602
~cc	0.756616	0.00149083	0.675766
solution coverage:	0.979873		
solution consistency:	0.616268		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.800898		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
~er~pd*~qcc*~cc*~sc*	0.327618	0.163623	0.741147
~it~er*pd*~cc*~sc*	0.265747	0.139396	0.840802
*it*er*~pd*~cc*~sc*	0.181141	0.0290719	0.925714
it~er*~pd*qcc*cc*sc*	0.144614	0.0290719	0.836206
*it*er*pd*qcc*cc*sc*	0.21804	0.102497	0.891768
solution coverage:	0.662318		
solution consistency:	0.745386		

4.4. To result in low levels of significantly improving current products. (~ pdi2)

****
TRUTH TABLE ANALYSIS
****
Model: *~pdi2 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.917526		
	raw coverage	unique coverage	consistency
	----------	----------	----------
it~pd*qcc*cc*sc*	0.294542	0.165539	0.923621
*it*er*~pd*qcc*~cc*~sc*	0.170501	0.0414976	0.956962
solution coverage:	0.33604		
solution consistency:	0.932416		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.917526		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*~pd*qcc*	0.439333	0.439333	0.790584
solution coverage:	0.439333		
solution consistency:	0.790584		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.917526		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
it~pd*qcc*cc*sc*	0.294542	0.165539	0.923621
*it*er*~pd*qcc*~cc*~sc*	0.170501	0.0414976	0.956962
solution coverage:	0.33604		
solution consistency:	0.932416		

4.5. To achieve high levels in producing new products based on existing technologies. (pdi3)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *pdi3 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.873418

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*pd*~cc*~sc*	0.287132	0.194485	0.920991
*it*er*~pd*~cc*~sc*	0.174632	0.0746324	0.904762
*it*er*pd*qcc*cc*sc*	0.213603	0.111029	0.885671
solution coverage:	0.482721		
solution consistency:	0.872425		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.873418

	raw coverage	unique coverage	consistency
	----------	----------	----------
pd	0.561765	0.369853	0.699954
er~sc*	0.224632	0.00808829	0.858146
er~cc*	0.286029	0.0110294	0.864444
solution coverage:	0.666912		
solution consistency:	0.714173		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.873418
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
~it~er*pd*~cc*~sc*	0.287132	0.194485	0.920991
*it*er*~pd*~cc*~sc*	0.174632	0.0746324	0.904762
*it*er*pd*qcc*cc*sc*	0.213603	0.111029	0.885671
solution coverage:	0.482721		
solution consistency:	0.872425		

4.6. To result in low levels of producing new products based on existing technologies. (~ pdi3)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *~pdi3 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff: 2
consistency cutoff: 0.812715

	raw coverage	unique coverage	consistency
	----------	----------	----------
it~pd*qcc*cc*sc*	0.274312	0.140367	0.845827
it~er*~pd*~qcc*~cc*~sc*	0.251376	0.116055	0.820359
*it*er*~pd*qcc*~cc*~sc*	0.152293	0.000917464	0.840506
solution coverage:	0.411468		
solution consistency:	0.765359		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff: 2
consistency cutoff: 0.812715

	raw coverage	unique coverage	consistency
	----------	----------	----------
it~er*	0.472477	0.237615	0.716771
*~pd*qcc*	0.412844	0.177982	0.73052
solution coverage:	0.650459		
solution consistency:	0.673315		

--- INTERMEDIATE SOLUTION ---

frequency cutoff: 2
consistency cutoff: 0.812715
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
it~pd*qcc*cc*sc*	0.274312	0.140367	0.845827
it~er*~pd*~qcc*~cc*~sc*	0.251376	0.116055	0.820359
*it*er*~pd*qcc*~cc*~sc*	0.152293	0.000917464	0.840506
solution coverage:	0.411468		
solution consistency:	0.765359		

4.7. To achieve high levels in producing new products based on new technologies. (pdi4)

****
TRUTH TABLE ANALYSIS
****

Model: *pdi4 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.803879		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*it*er*~pd*~cc*~sc*	0.190666	0.08217	0.910476
~it~er*pd*qcc*~cc*~sc*	0.181492	0.07858	0.897436
it~er*~pd*qcc*cc*sc*	0.148783	0.0390906	0.803879
*it*er*pd*qcc*cc*sc*	0.218588	0.0977263	0.835366
solution coverage:	0.420822		
solution consistency:	0.802281		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.803879		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*~er*qcc*	0.37495	0.0757878	0.649171
*pd*qcc*	0.429198	0.0781811	0.727519
er~sc*	0.25369	0.00877547	0.893258
er~cc*	0.317112	0.013562	0.883333
solution coverage:	0.637016		
solution consistency:	0.692541		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.803879		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
*it*er*~pd*~cc*~sc*	0.190666	0.08217	0.910476
~it~er*pd*qcc*~cc*~sc*	0.181492	0.07858	0.897436
it~er*~pd*qcc*cc*sc*	0.148783	0.0390906	0.803879
*it*er*pd*qcc*cc*sc*	0.218588	0.0977263	0.835366
solution coverage:	0.420822		
solution consistency:	0.802281		

4.8. To result in low levels of producing new products based on new technologies. (~ pdi4)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *~pdi4 = f(it, er, pd, qcc, cc, sc)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.883161

	raw coverage	unique coverage	consistency
	----------	----------	----------
it~pd*qcc*cc*sc*	0.264522	0.145007	0.895332
*it*er*~pd*qcc*~cc*~sc*	0.157961	0.0384456	0.956962
solution coverage:	0.302967		
solution consistency:	0.907384		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.883161

	raw coverage	unique coverage	consistency
	----------	----------	----------
*~pd*qcc*	0.38947	0.38947	0.756494
solution coverage:	0.38947		
solution consistency:	0.756494		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.883161
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
it~pd*qcc*cc*sc*	0.264522	0.145007	0.895332
*it*er*~pd*qcc*~cc*~sc*	0.157961	0.0384456	0.956962
solution coverage:	0.302967		
solution consistency:	0.907384		

Part 5: Configurations of main mentors to achieve high levels and result in low levels for each type of product innovation in formal R&D firms

5.1. To achieve high levels in redesigning packaging or significantly changing appearance design. (pdi1)

****
TRUTH TABLE ANALYSIS
****
Model: *pdi1 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	3		
consistency cutoff:	0.95		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect* ~enrdd*~pll*~fw*~ow*	0.209343	0.209343	0.95
solution coverage:	0.209343		
solution consistency:	0.95		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	3		
consistency cutoff:	0.95		
	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*	0.259145	0.259145	0.653333
solution coverage:	0.259145		
solution consistency:	0.653333		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	3		
consistency cutoff:	0.95		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect* ~enrdd*~pll*~fw*~ow*	0.209343	0.209343	0.95
solution coverage:	0.209343		
solution consistency:	0.95		

5.2. To result in low levels of redesigning packaging or significantly changing appearance design. (~ pdi1)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi1 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1
*** ERROR(Quine-McCluskey): The 1 Matrix is Empty. ***

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
erdd	0.197257	0.00326586	0.431429
ect	0.00326584	0	0.05
enrdd	0.00653168	0	0.05
pll	0.313521	0.122796	0.685714
fw	0.132593	0	0.406
ow	0.00326584	0	0.05
~tm~hrdd*	0.00653168	0	0.05
*~tm*mct*	0.0646636	0	0.495
*hrdd*mct*	0.122796	0.0613978	0.94
solution coverage:	0.455911		
solution consistency:	0.465333		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect* *~enrdd*~pll*~fw*~ow*	0.0163292	0.0163292	0.05
solution coverage:	0.0163292		
solution consistency:	0.05		

5.3. To achieve high levels in significantly improving current products. (pdi2)

****
TRUTH TABLE ANALYSIS
****
Model: *pdi2 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 3
consistency cutoff: 0.95

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect*~enrdd*~pll*~fw*~ow*	0.187525	0.187525	0.95
solution coverage:	0.187525		
solution consistency:	0.95		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 3
consistency cutoff: 0.95

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*	0.255823	0.255823	0.72
solution coverage:	0.255823		
solution consistency:	0.72		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 3
consistency cutoff: 0.95
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect*~enrdd*~pll*~fw*~ow*	0.187525	0.187525	0.95
solution coverage:	0.187525		
solution consistency:	0.95		

5.4. To result in low levels of significantly improving current products. (~ pdi2)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *~pdi2 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1
*** ERROR(Quine-McCluskey): The 1 Matrix is Empty. ***

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
erdd	0.136543	0.00394633	0.247143
ect	0.00394633	0	0.05
enrdd	0.00789266	0	0.05
pll	0.316496	0.133386	0.572857
fw	0.18311	0	0.464
ow	0.00394633	0	0.05
~tm~hrdd*	0.062352	0	0.395
*~tm*mct*	0.00789266	0	0.05
*hrdd*mct*	0.062352	0.0584057	0.395
solution coverage:	0.456985		
solution consistency:	0.386		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect*~enrdd*~pll*~fw*~ow*	0.0197317	0.0197317	0.05
solution coverage:	0.0197317		
solution consistency:	0.05		

5.5. To achieve high levels in producing new products based on existing technologies. (pdi3)

****
TRUTH TABLE ANALYSIS
****
Model: *pdi3 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 3
consistency cutoff: 0.95

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect*~enrdd*~pll*~fw*~ow*	0.228365	0.228365	0.95

solution coverage: 0.228365
solution consistency: 0.95

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 3
consistency cutoff: 0.95

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*	0.28125	0.28125	0.65

solution coverage: 0.28125
solution consistency: 0.65

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 3
consistency cutoff: 0.95
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect*~enrdd*~pll*~fw*~ow*	0.228365	0.228365	0.95

solution coverage: 0.228365
solution consistency: 0.95

5.6. To result in low levels of producing new products based on existing technologies. (~ pdi3)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi3 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1
*** ERROR(Quine-McCluskey): The 1 Matrix is Empty. ***

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
erdd	0.125	0.00290698	0.307143
ect	0.00290698	0	0.05
enrdd	0.0581395	0	0.5
pll	0.334302	0.110465	0.821429
fw	0.223837	0	0.77
ow	0.0552326	0	0.95
~tm~hrdd*	0.0581395	0	0.5
*~tm*mct*	0.00581395	0	0.05
*hrdd*mct*	0.0581395	0.0552326	0.5
solution coverage:	0.514535		
solution consistency:	0.59		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect*~enrdd*~pll*~fw*~ow*	0.0145349	0.0145349	0.05
solution coverage:	0.0145349		
solution consistency:	0.05		

5.7. To achieve high levels in producing new products based on new technologies. (pdi4)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *pdi4 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1
*** ERROR(Quine-McCluskey): The 1 Matrix is Empty. ***

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
erdd	0.209432	0.00253546	0.59
ect	0.0481744	0	0.95
enrdd	0.0689655	0	0.68
pll	0.0907708	0.0233265	0.255714
fw	0.0948276	0	0.374
ow	0.0025355	0	0.05
~tm~hrdd*	0.0507099	0	0.5
*~tm*mct*	0.0963489	0	0.95
*hrdd*mct*	0.0689655	0.020791	0.68
solution coverage:	0.330122		
solution consistency:	0.434		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect* ~enrdd*~pll*~fw*~ow*	0.140467	0.140467	0.554
solution coverage:	0.140467		
solution consistency:	0.554		

5.8. To result in low levels of producing new products based on new technologies. (~ pdi4)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *~pdi4 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1
*** ERROR(Quine-McCluskey): The 1 Matrix is Empty. ***

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
erdd	0.157002	0.0519693	0.41
ect	0.00273523	0	0.05
enrdd	0.0350109	0	0.32
pll	0.285011	0.0842451	0.744286
fw	0.171225	0	0.626
ow	0.0519694	0	0.95
~tm~hrdd*	0.0547046	0	0.5
*~tm*mct*	0.00547046	0	0.05
*hrdd*mct*	0.0350109	0.0322757	0.32
solution coverage:	0.464442		
solution consistency:	0.566		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 3
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
*tm*hrdd*~erdd*~mct*~ect*~enrdd*~pll*~fw*~ow*	0.121991	0.121991	0.446
solution coverage:	0.121991		
solution consistency:	0.446		

Part 6: Configurations of main mentors to achieve high levels and result in low levels for each type of product innovation in non-formal R&D firms

6.1. To achieve high levels in redesigning packaging or significantly changing appearance design. (pdi1)

****
TRUTH TABLE ANALYSIS
****
Model: *pdi1 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.95		
	raw coverage	unique coverage	consistency
	----------	----------	----------
tm~hrdd*~erdd*mct*~ect*~enrdd*~pll*~fw*~ow*	0.0638012	0.0638012	0.95
solution coverage:	0.0638012		
solution consistency:	0.95		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.95		
	raw coverage	unique coverage	consistency
	----------	----------	----------
mct	0.114506	0.114506	0.682
solution coverage:	0.114506		
solution consistency:	0.682		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.95		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
tm~hrdd*~erdd*mct*~ect*~enrdd*~pll*~fw*~ow*	0.0638012	0.0638012	0.95
solution coverage:	0.0638012		
solution consistency:	0.95		

6.2. To result in low levels of redesigning packaging or significantly changing appearance design. (~ pdi1)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi1 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
*** ERROR(Quine-McCluskey): The 1 Matrix is Empty. ***

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
erdd	0.0853278	0.00260144	0.273333
ect	0.0400624	0	0.385
enrdd	0.0775234	0	0.496667
fw	0.224766	0.037461	0.72
ow	0.0775234	0	0.496667
~tm~hrdd*	0.155047	0	0.496667
*~tm*mct*	0.0400624	0	0.385
*~tm*pll*	0.0827264	0.00260144	0.318
*hrdd*mct*	0.0400624	0	0.385
*mct*pll*	0.0775234	0	0.496667
solution coverage:	0.277836		
solution consistency:	0.410769		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
tm~hrdd*~erdd*mct*~ect* *~enrdd*~pll*~fw*~ow*	0.00520292	0.00520292	0.05
solution coverage:	0.00520292		
solution consistency:	0.05		

6.3. To achieve high levels in significantly improving current products. (pdi2)

****
TRUTH TABLE ANALYSIS
****
Model: *pdi2 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.95		
	raw coverage	unique coverage	consistency
	----------	----------	----------
tm~hrdd*~erdd*mct*~ect*~enrdd*~pll*~fw*~ow*	0.0708162	0.0708162	0.95
solution coverage:	0.0708162		
solution consistency:	0.95		

--- PARSIMONIOUS SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.95		
	raw coverage	unique coverage	consistency
	----------	----------	----------
mct	0.130824	0.130824	0.702
solution coverage:	0.130824		
solution consistency:	0.702		

--- INTERMEDIATE SOLUTION ---

frequency cutoff:	2		
consistency cutoff:	0.95		
Assumptions:			
	raw coverage	unique coverage	consistency
	----------	----------	----------
tm~hrdd*~erdd*mct*~ect*~enrdd*~pll*~fw*~ow*	0.0708162	0.0708162	0.95
solution coverage:	0.0708162		
solution consistency:	0.95		

6.4. To result in low levels of significantly improving current products. (~ pdi2)

****
TRUTH TABLE ANALYSIS
****
Model: *~pdi2 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
*** ERROR(Quine-McCluskey): The 1 Matrix is Empty. ***

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
erdd	0.097429	0.030221	0.36
ect	0.0324763	0	0.36
enrdd	0.075327	0	0.556667
fw	0.181326	0.030221	0.67
ow	0.0626974	0	0.463333
~tm~hrdd*	0.138024	0	0.51
*~tm*mct*	0.0324763	0	0.36
*~tm*pll*	0.067208	0.00225529	0.298
*hrdd*mct*	0.0324763	0	0.36
*mct*pll*	0.0626974	0	0.463333
solution coverage:	0.265674		
solution consistency:	0.453077		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
tm~hrdd*~erdd*mct*~ect* *~enrdd*~pll*~fw*~ow*	0.0045106	0.0045106	0.05
solution coverage:	0.0045106		
solution consistency:	0.05		

6.5. To achieve high levels in producing new products based on existing technologies. (pdi3)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
Model: pdi3 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff:          2
consistency cutoff:        0.95
                           raw           unique
                           coverage      coverage      consistency
                           ----------    ----------    ----------
tm*~hrdd*~erdd*mct*~ect*
~enrdd*~pll*~fw*~ow        0.0698529     0.0698529     0.95
solution coverage:         0.0698529
solution consistency:      0.95

--- PARSIMONIOUS SOLUTION ---
frequency cutoff:          2
consistency cutoff:        0.95
                           raw           unique
                           coverage      coverage      consistency
                           ----------    ----------    ----------
mct                        0.151471      0.151471      0.824
solution coverage:         0.151471
solution consistency:      0.824

--- INTERMEDIATE SOLUTION ---
frequency cutoff:          2
consistency cutoff:        0.95
Assumptions:
                           raw           unique
                           coverage      coverage      consistency
                           ----------    ----------    ----------
tm*~hrdd*~erdd*mct*~ect*
~enrdd*~pll*~fw*~ow        0.0698529     0.0698529     0.95
solution coverage:         0.0698529
solution consistency:      0.95
```

6.6. To result in low levels of producing new products based on existing technologies. (~ pdi3)

****
TRUTH TABLE ANALYSIS
****

Model: *~pdi3 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
*** ERROR(Quine-McCluskey): The 1 Matrix is Empty. ***

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
erdd	0.083945	0.0311926	0.305
ect	0.00458716	0	0.05
enrdd	0.0357798	0	0.26
fw	0.170642	0.0311927	0.62
ow	0.0357798	0	0.26
~tm~hrdd*	0.129358	0	0.47
*~tm*mct*	0.0334862	0	0.365
*~tm*pll*	0.0816514	0.00229359	0.356
*hrdd*mct*	0.00458716	0	0.05
*mct*pll*	0.0357798	0	0.26
solution coverage:	0.244495		
solution consistency:	0.41		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
tm~hrdd*~erdd*mct*~ect*~enrdd*~pll*~fw*~ow*	0.00458716	0.00458716	0.05
solution coverage:	0.00458716		
solution consistency:	0.05		

6.7. To achieve high levels in producing new products based on new technologies. (pdi4)

```
**********************
*TRUTH TABLE ANALYSIS*
**********************
```

Model: *pdi4 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.95

	raw coverage	unique coverage	consistency
	----------	----------	----------
tm~hrdd*~erdd*mct*~ect* ~enrdd*~pll*~fw*~ow*	0.0757878	0.0757878	0.95
solution coverage:	0.0757878		
solution consistency:	0.95		

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.95

	raw coverage	unique coverage	consistency
	----------	----------	----------
mct	0.168728	0.168728	0.846
solution coverage:	0.168728		
solution consistency:	0.846		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 0.95
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
tm~hrdd*~erdd*mct*~ect* ~enrdd*~pll*~fw*~ow*	0.0757878	0.0757878	0.95
solution coverage:	0.0757878		
solution consistency:	0.95		

6.8. To result in low levels of producing new products based on new technologies. (~ pdi4)

****
TRUTH TABLE ANALYSIS
****
Model: *~pdi4 = f(tm, hrdd, erdd, mct, ect, enrdd, pll, fw, ow)*
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
*** ERROR(Quine-McCluskey): The 1 Matrix is Empty. ***

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1

	raw coverage	unique coverage	consistency
	----------	----------	----------
erdd	0.131216	0.0396991	0.523333
ect	0.0259089	0	0.31
enrdd	0.065608	0	0.523333
fw	0.137066	0.0238195	0.546667
ow	0.0497284	0	0.396667
~tm~hrdd*	0.115336	0	0.46
*~tm*mct*	0.00417886	0	0.05
*~tm*pll*	0.0480568	0.00208943	0.23
*hrdd*mct*	0.0259089	0	0.31
*mct*pll*	0.0279983	0	0.223333
solution coverage:	0.248642		
solution consistency:	0.457692		

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 2
consistency cutoff: 1
Assumptions:

	raw coverage	unique coverage	consistency
	----------	----------	----------
tm~hrdd*~erdd*mct*~ect*~enrdd*~pll*~fw*~ow*	0.00417886	0.00417886	0.05
solution coverage:	0.00417886		
solution consistency:	0.05		

PUBLICATIONS

Papers submitted and published in journals

Tieng, K., Amna, J., Jeenanunta, C., and Youji, K. (2020) Applications of Fuzzy Logic to Reconfigure Human Resource Management Practices for Promoting Product Innovation in Formal and Non-Formal R&D Firms, *Journal of Open Innovation: Technology, Market, and Complexity, 6*(2), 38.

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Tieng, K., Sumetthapiwat, S., Dumrongsiri, A., and Jeenanunta, C. (2016). Heuristics for Two-Dimensional Rectangular Guillotine Cutting Stock. *Thailand Statistician Journal, 14*(2), 147-164.

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Tieng, K., Jeenanunta, C., and Youji, K. [*Under Review*], "Knowledge creation practices for innovation in the Thai manufacturing context", *International Journal of Human Resource Development and Management*.

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