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Abstract

The concept of a national innovation system has been recognized as an essential tool to study the process and evolution of developed and developing countries' economic development. To analyze the NIS to find the systemic problems, we analyze it at the firm, sector, and national levels.

Chapter 2 aims to review the literature about the expanded NIS, which is appropriate to the developing countries context. NIS in developing countries has three stages of development, namely emerging, maturing, and mature NIS, based on the capabilities escalator. The three levels of capabilities escalator are management and production capabilities, technology absorption and adoption capabilities, and inventions and technology generation capabilities. In an emerging NIS, management capabilities and individual competencies are the central units of analysis. It represents the demand side of NIS, which the supply side should consider to upgrade the NIS. When a country moves to the next level of development, it is characterized as a fragmented or dual innovation system. In this system, technology adoption and absorption capabilities become the central unit of analysis. However, the management capabilities still need to be upgraded. Finally, when the country moves to become developed, it is characterized by a mature NIS, in which invention and technology generation capabilities are the central unit of the analysis; meanwhile, the previous two capabilities still need to be upgraded.

Chapter 3 aims to analyze the NIS of Cambodia using the expanded concept of NIS proposed in Chapter 2 to identify its problems and possible solutions. Cambodian NIS can be characterized as an emergent innovation system. Management and production capabilities, which are the first level of the three-level capabilities escalator, are still low. This low level derives from the fact that Cambodia lacks management extension services. Limited management and production capabilities explain why R&D investment is low among Cambodian firms. Another possible reason is the lack of complementary factors, such as skilled labor and financing, which could help domestic firms earn a higher return on their R&D. Furthermore, Cambodia faces high exporting costs, limited national qualification infrastructure, and burdensome business regulations. These problems result in the limited number of medium-sized exporters in the Cambodian export structure and a small number of startups and tech SMEs. These problems also explain why linkages between multinational firms and the domestic economy are still weak. Cambodian NIS could be upgraded by targeting innovation policy instruments to resolve the systematic problems found above.

Chapter 4 aims to analyze the Cambodian NIS applying the expanded NIS concept proposed in Chapter 2. This concept can be used for analysis to understand the determinants of innovation inputs, the relationship between innovation inputs and innovation outcomes, and the relationship between innovation outcomes and labor productivity at the firm-level in Cambodia. To respond to the objectives, we adopt and extend the original CDM model developed by Crépon, Duguet, and Mairesse (1998) to the Cambodian economic context as a developing country. The generalized structural equation model has been applied to a sample of 373 firms.

Cambodia's NIS is functioning as an emergent innovation system. The business environment has been improved in general but is still not conducive to the national innovation performance. Government regulations and telecommunications obstacles seem to be enhanced to support R&D activities. In addition, a competitive environment is favorable for firms to invest in R&D and product innovation. Physical capital has been accumulated to significantly impact R&D activities and labor productivity, while large firms tend to produce organizational innovation and labor productivity. However, barriers in accessing finance impede the firms from investing in R&D. Human capital is still limited since firms have invested substantially in staff training to develop the innovation outcomes. International integration of Cambodian firms into international markets and global value chains is limited since international trade obstacle is likely to decrease R&D investment. Foreign-owned firms tend not to invest in R&D but tend to produce product innovation, while importers are not likely to invest in R&D but are likely to produce organizational innovation.

The constraints in human capital, access to finance, and high trade costs can explain why

Cambodia has a low level of R&D (at only 10% of sample firms). Firms investing in internationally recognized certification tend to increase the R&D investment. This also happens with firms investing in foreign technology licensing and new tangible assets. This finding suggests that these technological factors complement R&D activities, meaning that firms learn new knowledge and technologies through investing in these three sources.

Cambodian firms apply only basic management and organizational capabilities. There are two explanations. First, firms interact with other firms or public institutions to learn technological innovation, product and process innovations. However, Cambodian firms apply technological cooperation to produce only process innovation, which means that they have limited management capabilities so that they do not intend to interact to develop product innovation. Second, the predicted value of R&D investment has a positive impact on a firm's propensity to produce all types of innovation outcomes, but only the predicted value of product innovation has a positively significant but small impact on labor productivity, suggesting the limited management capabilities among Cambodian firms.

The interaction between firms and between firms and other firms or public institutions is still low. The firms that use technological cooperation and subcontracting to learn new knowledge and technologies represent only 14% and 7% of the sample firms, but firms that contact clients and suppliers using website and email represent up to 27% and 56%, respectively. Cambodian firms apply technological cooperation to produce process innovation but subcontracting to introduce product and organizational innovations. They contact clients and suppliers to learn new product characteristics to develop product innovation.

Chapter 5 aims to understand trade specialization patterns during 2001-2019 at the country and industry level. To achieve this research objective, we calculate trade specialization indices on the sample of 253 high-tech and low-tech industries. These indices have been classified into two periods to analyze the patterns of trade specializations at the industry level. Then, the Galtonian regression has been run on equations of trade specialization pattern to understand the pattern of trade specialization at the national level.

Cambodia has an incipient science and technology system to support domestic firms' organizational and technological capabilities, promoting the industrial transformation. It has four growing high-tech industries, 16 emerging high-tech industries, 11 marginal high-tech industries, and 23 losing high-tech industries. Also, it has 11 growing low-tech industries, 12 emerging low-tech industries, 73 marginal industries, and 11 losing low-tech sectors.

Cambodia has concentrated in only a few established industries; however, it starts to widen its trade specialization slightly in both low-tech and high-tech industries but with the slow mobility within and between sectors in the long period at the national level. Cambodian industries reveal the stickiness and incremental change, which means that the trade specialization's initial values move slowly to the average within sectors. The degree of specialization shows the decrease in dispersion of the trade and technological specialization, which address slow mobility between sectors toward the broad pattern of specialization. According to Unger (1988), this finding suggests that Cambodia lacks the Schumpeterian entrepreneurs, which have the organizational and technological capabilities to learn and adapt the new knowledge and technologies into the local context before diffusing them in the Cambodian economy to build the national competitiveness in the international markets.

Chapter 6 aims to understand trade specialization and technological specialization patterns and their relationship in 2001-2019. To achieve this research objective, we calculate the indices of trade specialization and technological specialization on the sample of 90 high-tech industries. The Galtonian regression has been run on equations of trade and technological specialization patterns and equations of their causal relationship to understand the patterns of trade and technological specializations and their relationship at the national level. Then these indices have been classified into two periods to analyze the patterns of trade and technological specializations and their relationship at the industry level.

The result shows that Cambodia has concentrated in only a few established high-tech industries; however, it starts to widen its trade specialization slightly in high-tech industries but with the slow mobility within and between sectors in the long period at the national level. Cambodia starts to diversify its technological specialization pattern with a significant change in the long period at the national level. This suggests that Cambodia is further its structural transformation into high-tech industries in the extended period. However, it represents the low mobility effect in both trade and technological specializations in the last two periods. This result is consistent with the analysis of their relationship, which shows that technology influences trade in the first period, but this relationship is reversed in the last two periods. This relationship can be interpreted that Cambodia has adequate skilled workers in the first period to attract domestic firms and FDIs in high-tech industries. However, when these human resources are filled up by the existing firms in the first period, Cambodia lacks this human capital in the last two periods.

Cambodian high-tech industries reveal the stickiness and incremental change, which means that the trade specialization's initial values move slowly to the average within sectors. The degree of specialization shows the decrease in the dispersion of trade and technological specialization distribution, which addresses slow mobility between sectors toward the broad pattern of specialization. According to Unger (1988), this finding suggests that Cambodia lacks the Schumpeterian entrepreneurs, which have the organizational and technological capabilities to learn and adapt the new knowledge and technologies into the local context before diffusing them in the Cambodian economy to build the national competitiveness in the international markets.

The implications of industries' movement show that no sector moves from a quadrant with trade advantage to a quadrant with both trade and technological advantages. This implication is different from that of the East Asian countries, which commonly developed their electronics industries by gaining from trade advantage before they develop further into both trade and technological advantages. There is also no industry move from the quadrant with technology advantage to quadrant with trade advantage and to quadrant with both advantages, representing the technology push. This implication suggests that Cambodia has not committed to developing the technological infrastructure to support the domestic firms in upgrading their organizational and technological capabilities.

However, two high-tech industries, including Motorcycles and bicycles and Equipment for distributing electricity, move from the quadrant without trade and technological advantages to the quadrant with both of them. Cambodia also has 14 high-tech industries move from the quadrant without both advantages to the quadrant with trade advantage. It seems that Cambodia can achieve the initial success in these high-tech industries through learning by doing related to the linkage between multinational firms and domestic firms to improve trade specialization. It is uncertain whether this trade specialization will enhance technological specialization in the future. Sectoral innovation policies should be developed to upgrade high-tech industries' technological capabilities since supporting them can further diversification into nearby products in the product space faster than low-tech industries (Hausman et al., 2006, Freeman et al., 1988).

Chapter 1: Introduction

Background and Rationale of the Study

The national innovation system (NIS) concept is essential to analyze the innovative performance at the firm, industry, and national levels to develop selective innovation policies. NIS is the interaction between universities, public research institutes, government agencies, financial institutions, and domestic firms with the appropriate institutional framework to improve domestic firms' technical, financial, and commercial competencies to learn new knowledge and technologies to imitate or innovate successfully (World Bank, 2010). NIS in developed countries is different from developing countries. Developed countries invest in R&D and gain a high return from it; meanwhile, developing countries experience low returns (Cirera et al., 2017). This phenomenon may derive from the lack of complementary and institutional factors in developing countries. The complementary factors include physical capital, human capital, and management capabilities in addition to the R&D or knowledge capital.

Suppose the government wants to incentivize the domestic firms to accumulate knowledge capital and other complementary factors. In that case, it must consider a wide range of institutions to create the appropriate macroeconomic and competitive environments, promote good trade regimes and international networking, and remove the barriers to the accumulation of those capitals. The business environment, including credit markets, entry and exit barriers, business and regulatory climate, the rule of law, and labor market rigidities, needs to be improved to support firms' obtaining those resources (Cirera et al., 2017). In this sense, when developing countries adequately accumulate these complementary factors through improving the general business environment, they will gain a higher return on R&D investment.

Chaminade et al. (2018) classify the dynamic evolution of innovation system into three phases according to the development stages: emergent innovation system for low- and lower-middle-income countries, fragmented one for upper-middle-income countries, mature one for high-income countries. Over time, a country with an emergent innovation system may evolve to become a mature one. Sometimes, a country with a mature innovation system can evolve to become emergent or fragmented. It is necessary to assess the NIS to know its position in the three phases of the evolution of the innovation system to understand the systemic problems to adopt the selective innovation policies to upgrade the NIS to move up to the next step. An emergent innovation system with a low education level of citizens and limited management capabilities needs to support the competence building and firm capability upgrading to avoid the poverty trap to move to the maturing one. A fragmented innovation system with a low level of technological capabilities needs to upgrade them by promoting the linkage between industry and the knowledge providers. Furthermore, sectors with short-cycled technologies should be developed to avoid the upper-middle-income country trap and move to become a mature innovation system. For preventing the lock-in in the old technologies, policymakers should connect their country's mature innovation system with the global innovation networks to be alert with new technological opportunities and new market demand.

Cambodia has the vision to become an upper-middle-income country in 2030 and a high-income country in 2050. Since Cambodia has achieved an average growth rate of 7.6% for the last two decades (World Bank, 2017b), it can achieve this vision within the schedule if it can maintain an annual growth rate of around 7%. Cambodia has been classified as a lower-middle-income country since 2016. According to Chaminade et al. (2018), its NIS may be functioning as an emergent innovation system. Cambodia needs to support the competence building and management capabilities to upgrade its innovation system to become a maturing one. It needs to not only avoid the "poverty trap" but also avoid the "upper-middle-income trap," which its wage rate cannot compete with poorer countries, and its innovation capabilities cannot compete with more advanced countries. Although there is strong growth, Cambodia still does not have the appropriate selective innovation policies to coordinate the generation, adaptation, and diffusion of the Cambodian economy's knowledge and technologies (OECD, 2013). Cambodia has adopted many development strategies and policies to maintain the growth rate of 7%, such as Rectangular Strategy IV, Industrial Development Policy 2015-2025, Cambodia Trade Integration Strategy and Trade SWAP Roadmap 2014-2018, and National Science and Technology Master Plan 2014-2020. According to the OECD (2013), these development strategies and policies do not state any theoretical framework to explain them to facilitate the practitioners to understand and easily implement them. Furthermore, a few studies have been done to analyze the Cambodian economic situations applying the NIS concept to understand the systematic problems for adopting appropriate selective innovation policies.

This study will analyze Cambodian NIS applying the NIS conceptual framework to define the systematic problems and find the selective policy solutions to upgrade the NIS to help Cambodia catch up with the region's more advanced economies. Then, it discovers the relationship between innovation input investments, innovation outcomes, and productivity at the firm-level. Finally, it will also help improve the understanding of the patterns of trade and technological specializations and their relationship at the national and industry levels, which can help develop Cambodian industries' competitive advantage.

Research Topics

1. Upgrading the National Innovation System for Catching Up in a Late-Industrializing Country, Cambodia
2. Innovation and Productivity at the Firm-Level: Can Cambodia Catch up with the Technological Frontier Economies?
3. Transformation of Competitive Advantages in Cambodia: Analysis of Trade and Technological Specialization

Objectives of the study

- To understand the systematic problems of the emerging innovation system in Cambodia and the appropriate solutions to resolve them to develop a well-functioning NIS.
- To explore the complementary factors and institutions affecting the innovation input investments and understand the relationship between innovation input investments, innovation outcomes, and labor productivity at the firm level.
- To find policy suggestions to develop the competitive advantage of marginal, emerging, and growing high value-added industries by analyzing the patterns of trade and technological specializations and their relationship at the national and industry levels.

Significance

This study may help improve the understanding of Cambodia's NIS position in comparison with neighboring countries and can use it to develop selective innovation policies to handle market failures, systemic failures, and capability failures to facilitate the nationwide learning processes for upgrading Cambodian NIS.

Data and Methodology

The data set of firm-level innovation is obtained from Enterprise Surveys of the World Bank in Cambodia in 2016 and trade data from the international trade center's website from 2001 to 2019. The research methodology will be discussed in each chapter.

The study will be conducted as follows. Chapter 2 focuses on the literature review of the NIS concept in both developed and developing countries to adopt the conceptual framework of NIS in the developing countries context. In chapter 3, the Cambodian innovation system will be analyzed by reviewing the literature related to the Cambodian economy using the conceptual framework proposed in Chapter 2. Chapter 4 also examines the Cambodian NIS. We use the Cambodia Enterprise Survey 2016 data set from World Bank to study the relationship between innovation inputs, innovation outcomes, and productivity and apply the CDM model proposed by Crépon, Duquet, and Mairesse (1998). Chapter 5 will study the trade and technological specialization patterns and their relationship to understand the Cambodian industries' competitive advantage to find ways to upgrade the sectoral innovation systems to support Cambodia's structural transformation. Finally, Chapter 6 will conclude and provide policy suggestions.

Chapter 2: National Innovation Systems in Developing Countries: Conceptual Framework

2.1 Introduction

The national innovation system (NIS) is a hot topic that researchers in both developed and developing countries have studied to create a social and technological infrastructure aimed at promoting economic growth. Freeman (1982) developed the NIS concept using a historical perspective based on Friedrich List's concept of national production system, and his analysis of how Germany and Japan caught up with the United Kingdom. He concluded that laggard economies need to set the rules of the game at the national level in order to upgrade the domestic firms' technological capabilities and allow them to compete successfully in international markets. On the other hand, Lundvall (1985) conceived the NIS concept as a framework in which countries need to accumulate competences and resources among users and producers at the national level in order to achieve international specialization in potentially new techno-economic paradigms. Later, Lundvall (1992, 2010a) synthesized and combined the two aforementioned visions and developed the modern concept of NIS, which includes narrow and broad definitions. The narrow definition refers to organizations and institutional set-ups such as R&D departments, technological institutes, and universities, which affect searching and exploring activities. The broad one refers to economic structure and institutional factors affecting the learning process, including production systems, marketing systems, and finance systems. This concept is apt to the context of developed countries: since they have an advanced business environment able to accumulate complementary factors such as physical capital, human capital, and managerial capital, their NIS focuses only on R&D activities.

On the contrary, NIS in developing countries can be characterized as emerging or fragmented innovation systems since they are not functioning correctly. They may have a low level of capabilities among actors, a lack of linkages among them, or a low level of R&D activities. The low level of capabilities derives from the 'capability failure', while the lack of connections among actors derives from the 'systemic failure'. Besides, the low level of R&D activities emanates from a 'market failure'. According to Cirera et al. (2017), developing countries face an 'innovation paradox' in three dimensions. First, they have a low or negative return on R&D when they are further from the knowledge frontier, because they lack significant complementary factors such as physical capital, human capital, and management capabilities in addition to R&D capital. Second, even though managerial and organizational capabilities are essential for firms to manage the adoption and development of technologies, the firms don't initiate by themselves their effort to invest in upgrading their management capabilities. Third, since developing countries have a lower level of complementary factors than developed countries, the scope and magnitude of their NIS are more complex than the latter; however, their government capabilities are weaker. Maloney (2017) has proposed an expanded NIS concept in the context of developing countries, based on the role of various organizations and institutions to support firms in accumulating complementary factors such as physical capital, human capital, and managerial capital, rather than focusing only on R&D activities.

Chapter 2 will be organized as follows. Section 2.1 will focus on the definition of NIS, while section 2.2 on the evolution of the concept. By reviewing an extensive literature, we adopt a conceptual framework of NIS in section 2.3, which has three development stages: emerging, maturing, and mature NIS, based on the capabilities escalator. The three levels of capabilities escalator are management and production capabilities, technology absorption and adoption capabilities, and invention and technology generation capabilities. In an emerging NIS, management capabilities and individual competencies are the central units of analysis and mainly represent its demand side, which the supply side should consider to upgrade the NIS. Section 2.4 will conclude.

2.2 Definition of National Innovation System

Lundvall (2010b) proposed the NIS definition, which recent researchers commonly use because it is relevant for both developed and developing countries. It is shown as the following:

> The NIS is an open, evolving, and complex system that encompasses relationships within and between organizations, institutions, and socio-economic structures that determine the rate and direction of innovation and competence-building emanating from processes of science-based and experience-based learning. (Lundvall, 2010b, P. 6).

Several points are addressed in this definition. First, it specifies that interactive learning and innovation result from a combination of institutional set-ups and socio-economic structure. The socio-economic structure represented by industrial sectors reflects what people know and what they learn from production and trade specialization. This specification is fundamental for developing countries to enable structural transformation. Remarkably, they can use the institutions supporting competence building such as education and training organizations to build the new skills set to further diversification their industrial sectors. Second, it specifies both work organization within firms and inter-organizational relationships to promote interactive learning and innovation. However, most NIS scholars focus on the former in only formal organizations, which is not right to the developing countries context, representing the large share of informal firms in the economic structure.

Third, the definition also addresses the importance of competence building as the other side of the innovation process. Policy-makers can help support competence building by encouraging individuals to learn and promoting firms to build their capabilities when confronting a competitive environment and technological changes (Lundvall, 2010b). Finally, the definition is a broad one referring not only to science-based but also to experience-based learning. Knowledge and competence can be upgraded by scientific community research processes and by learning by doing and learning by interacting. The knowledge in traditional and indigenous sectors is tacit and difficult to move, requiring learning by interacting. In this sense, on-the-job training, technical schools, and farmers' training due to their learning needs in their working life are necessary apart from university training (Chaminade et al., 2018).

2.2.1 Narrow Definition

The narrow definition focuses on developing radical innovations and science-based knowledge under the support of STI (science, technology, and innovation) institutions, such as universities, R&D institutes, and technology extension centers. It derives from the old form of the national science system, in which the development of innovations is the linear consequence of R&D activities (Chaminade et al., 2018). According to Lundvall (2007), it originates from the authors in the United States, such as Nelson (1993), since the United States' economic growth depends mainly on science-based sectors, which require support from the national science system.

The national science system is essential for both developed and developing countries. Freeman (1982) recognized the role of R&D departments in large firms to explain how Germany and the United States overtook Great Britain. These two big countries tried to upgrade their national knowledge infrastructure to support the R&D activities of their domestic firms to build their national competitiveness. Developing countries, such as Asian countries, developed their national R&D system to import and absorb globally available new technologies and adapt them to the local context before diffusing and using them in the whole economy (Freeman, 1995).

2.2.2 Broad Definition

NIS's broad definition focuses on both STI learning mode, developing radical innovations and science-based knowledge, and DUI (doing, using, and interacting) learning mode, mainly producing experience-based knowledge and incremental innovations (Chaminade et al., 2018). The definition of NIS is broad when it uses an overall sense of innovation, including the development or the importation of new technologies and their diffusion and use in the national system. The institutional framework includes STI institutions promoting science-based learning and DUI institutions promoting experience-based learning. The latter institutions involve national education and training policies, labor market policies, and work organizations that shape human resources and interactive learning. In this sense, definitions developed by Freeman and Lundvall are broad because Lundvall (1988, 1992) included the user-producer interaction approach promoting learning by doing, learning by using, and learning by interacting, while Freeman (1987) referred to national systems of production as the learning sources of the national innovation systems.

Box 2.1 Definitions of National Innovation System
"The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies" (Freeman, 1987, p. 1).
"A system of innovation is constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge and a national system encompasses elements and relationships, either located within or rooted inside the borders of a nation state" (Lundvall, 1992, p. 2).
"Set of institutions whose interactions determine the innovative performance of national firms" (Nelson, 1993, p. 5).

2.3 Evolution of National Innovation System Concept

2.3.1 Freeman's Contribution to Modern NIS Concept

The concept of NIS was explicitly used the first time by Freeman (1982, 2004). His study has contributed to the modern NIS concept in which national technological infrastructure impacts trade specialization, national competitiveness, and catching up. Using a historical perspective, Freeman (1982) identified R&D and patenting as the main factors affecting the international competitiveness of Germany and Japan. He referred to Friedrich List's national production system concept, which recognizes the importance of mental capital and the protection of infant industries to promote industrial development and catching up. List (1841) was strongly critical of the free trade theory introduced by Adam Smith. He claimed that Adam Smith does not recognize the importance of mental capital and the quality of labor force as the power to support the productive manufacturing industries. List incorporated many factors, such as the financial market and national education system, which play a vital role in building national competitiveness. Based on this concept, Freeman can explain how Germany can catch up with Great Britain and how Japan can catch up with the United States and European counterparts.

Freeman followed Schumpeter's definition of innovation, which is "the commercial realization or introduction of a new product, process, or system in the economy" (Freeman, 1982, p. 9). According to this definition, the entrepreneur plays a vital role in matching technologies and markets to produce new products or processes meeting user needs. Catching up economies can develop their national competitiveness by promoting the "coupling mechanisms" of education systems, scientific institutions, R&D departments, production units, and markets under the support of institutional changes.

According to Chaminade et al. (2018), there are three types of inspirations for Freeman to develop the full-blown NIS concept in Freeman (1987). Firstly, when he cooperated with Carlota Perez to create the concept of techno-economic paradigms, he suggested developing the institutions, organizations, and routines to accompany the development of new techno-economic paradigms to cope with the radical changes (Freeman et al., 1988). Secondly, when he provided lectures to his former students from Latin American developing countries in SPRU, he insisted on creating a science and technology system to support economic development while recognizing the inequalities and class relationships as barriers to upgrading NIS. Thirdly, when he worked with the Aalborg group in the early 1980s to develop the NIS concept for small high-income countries, he gained a user-producer interaction approach developed by the Aalborg group complementary to his perspective of the national science system.

Later, he used his experience in the early 1980s to develop the full-blown Japanese innovation system, including the national science system, work organizations, labor market organizations, and national education systems to promote interactive learning and innovation. In particular, Freeman (1988) used modern organization and innovation theories to explain Japanese NIS explicitly. He explained how the Japanese innovation system elements interact to build national competitiveness in the new techno-economic paradigms. These elements include internal organization of firms, inter-firm relationships, public sectors, national education system, and R&D system.

Lundvall (2015) noticed that Freeman (1982) provided hypotheses through a historical perspective, which motivated Jan Fagerberg to study the innovation systems by adopting new research methodologies to measure the impact of national technological infrastructure on economic growth and catching up in the quantitative measurement.

Fargeberg et al. (2007) studied how national innovation systems impacts economic development by adopting four capabilities: innovation system, governance, political system, and openness, using the factor analysis method on 25 indicators for the sample of 115 countries. He also included historical, geographical, and natural conditions in the synthetic framework.

The authors found that a well-functioning innovation system correlates positively with the level of economic development. Hence, a country that wants to catch-up has to upgrade its NIS. They also found that governance also has a positive relationship with growth. They argued that an appropriate institutional framework is assertive in applying a western-style political system in institutional arrangements, even though the assertion is relatively weak. This empirical study shows that when rich countries succeed in adapting their governance to the western political system, developing countries fail to do so. There is evidence that some countries that adapt to political systems different from western ideals are also catching up very fast. Those countries include China, Vietnam, Asian Tigers before the 1980s, and pre-world-war-two Japan.

Furthermore, the authors found that openness impacts growth only by a small margin, and again it has been applied successfully only in rich countries. Since low-income countries have low absorptive capacities, it is challenging for them to benefit from knowledge spillovers diffused by foreign direct investments. Finally, they found that developing countries are challenging to establish a well-functioning innovation system because they may have unfavorable geography, nature, and history, and these factors continuously weaken their economies even further.

In another recent study, Fagerberg (2015) used stylized facts from the Commission Innovation Survey (CIS). They proposed a synthetic framework of NIS, which is also a broad definition. NIS is an interaction between different processes in different areas such as knowledge, skills, industries, finance, and innovation supporting institutions to promote technological dynamics in various sectors. By definition, technological dynamics is the output of the innovation system, which appears as the innovation, diffusion, and use of new technologies. The firms need complementary processes such as knowledge, skills, demand for innovation, finance, and innovation supporting institutions to help these firms produce, diffuse, and use new technologies. For example, suppose they have superior knowledge but lack skills to exploit it or lack the market for the latest technologies, or lack finance to invest in their innovation activities. In that case, they cannot develop, diffuse, and use the new technologies successfully due to the "unsatisfactory issues" caused by these systemic problems. Policymakers need to carefully evaluate the NIS to determine these nonfunctioning processes in the whole system in order to propose selective innovation policies to tackle these systematic issues.

2.3.2 Lundvall's Contribution to the Modern NIS Concept

Lundvall (1985) developed a user-producer interaction approach to explain how producers and users create product innovation based on the analysis of four industrial complexes in Denmark conducted in the MIKE project. He found that producers' uneven power dominance and the uneven distribution of competent workers between producers and users at the national level are the barriers to developing new technologies. Lundvall (1985) strongly criticized neoclassical economics and transaction cost theory developed by Williamson (1975) by suggesting that both "pure market" and "pure hierarchy" forms cannot produce product innovation. However, he argued that it could be developed through an "organized market" in the user-producer interaction approach. He also studied the linkage between university and industry, recognized as an innovation system the first-time printed reference.

Later, Lundvall (1988) defined user and producer interaction as micro-foundations in the NIS concept. NIS includes the interactions between universities and industries, between suppliers and producers, and between producers and users at the national level. These interactions can be facilitated by reducing the distance of geography, culture, and language. The bottlenecks and specific problems in user organizations' production units could be identified and used as inputs for R&D units, technological institutes, or universities to search and explore to find appropriate solutions. In this sense, final users, including workers, consumers, and public sectors, with high competencies are essential to enhance innovative performance. For example, a country with trade specialization of specific commodity sectors can support developing production technologies in the same sectors and related ones. These induced innovations derive from the fact that the production technology producers create their product innovation using the particular needs of users. In contrast, the users can access the technological opportunities from the producers.

The modern concept of NIS in Lundvall (1992) originates from the combination of ideas developed by Freeman (1982) and by Lundvall (1985) (Lundvall, 2015). While Freeman (1982) focused on developing the national technological infrastructure to obtain national competitiveness, Lundvall (1985) focused on interactive learning and innovation between users and producers at the national level. Lundvall (1992, 2010a) developed the NIS concept by distinguishing the narrow definition from the broad one. The narrow one includes "organizations and institutions involved in searching and exploring – such as R&D departments, technological institutes, and universities" (p.13). The broad definition includes "all parts and aspects of the economic structure and the institutional set up affecting learning as well as searching and exploring – the production system, the marketing system, and the system of finance present themselves as sub-systems in which learning takes place" (p. 13).

On the other hand, Lundvall (1992) recognized that his approach is similar to Freeman's (1988) approach, which focuses on work organization within firms and interaction between firms and other firms or public organizations, and the support from the national education system. On the other hand, he recognized the importance of institutional set-up in Nelson's (1988) approach, strengthening the interaction between firms and external knowledge infrastructures, such as R&D institutes, technology extension centers, and universities.

The modern concept of NIS of Lundvall (1992) has some characteristics similar to Porter (1990) but a different one. Porter (1990) defined four determinants, such as firm strategy, factor conditions, demand conditions, and supporting industries, which could help develop the international competitiveness of a nation's single industries. Lundvall (1992) defined an innovation system as to how the economic structure and institutions promote the learning process and innovation. This concept is similar to Porter's approach in three points. First, the learning process and innovation are similar to new "factor conditions" in Porter's approach. Second, "demand factors" and "supporting industries" represent the economic structure, promoting interactive learning and innovation. Third, firm strategy, which includes both cooperation and competition approaches, is the institutional set-up to promote interaction between firms. Firms set up and implement their strategies to interact with supporting industries to access the technological opportunities and interact with user organizations to learn new market needs. Through this process, they can develop the new factor conditions. However, there is one different characteristic between the two approaches. Porter treats the national system as the environment in developing a nation's single industries; however, Lundvall uses it as a unit of analysis on its own.

According to Chaminade et al. (2018), the modern NIS concept developed by Freeman (1987, 1988) and Lundvall (1992, 2002) intertwine. After withdrawing his directorship from SPRU, Christopher Freeman participated in the collaboration projects with the IKE group at Aalborg University in the early 1980s. He contributed with the national science system concept to the full-blown NIS concept, while Lundvall contributed his user-producer interaction approach. Freeman learned from Friedrich List about the national production system, while Lundvall learned it from French Marxist scholars, such as de Bernis and Paillot. In 1987, Freeman developed and used explicitly this intertwined NIS concept for studying the Japanese Innovation System, while Lundvall created it in his 1992 book and later used it for studying Denmark Innovation System in 2002.

The user-producer interaction approach of Lundvall (1985) also induces economic geographers such as Morgan, Cooke, Gertler, Maskell, Asheim, and Storper to further study on innovation system concept in the context of geographic space (Lundvall, 2015).

To develop the NIS concept as an analytical concept and development tool, Lundvall (2007), based on an innovation survey in Denmark conducted in the DISKO project, defined NIS's boundaries into two stages: the core of NIS and the wider setting. First, the core of NIS, micro-structures, refers to the interaction within and between firms and between firms and knowledge infrastructures, such as technical institutes and universities, to promote interactive learning and innovation. It is crucial to explain international differences in these respects, which can help policymakers to understand how NIS works and to adopt organizations and institutions appropriately at the meso-level and macro-level to support interactive learning and innovation at the firm level.

Second, a wider setting could help shape people working within firms and the relationship between firms and other firms or knowledge infrastructure to support the core. The wider setting includes education and training policies, labor market policies, financial markets, product-market competitions, welfare regimes, and intellectual property rights. If the core of NIS evolves at a higher speed than the wider setting, radical national reform should be in place to support the core. On the contrary, if the micro-structures have low competencies, the wider setting's reform will help resolve the disadvantages.

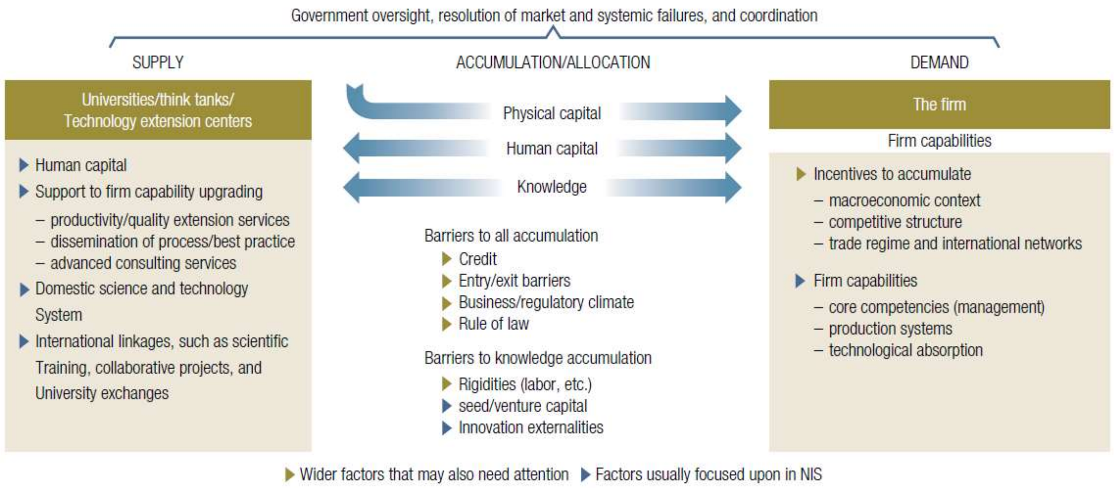
As stated above, the modern NIS concept developed by Lundvall has been the origin of the regional innovation system (RIS) concept created by economic geographers. Asheim et al. (2018) developed the RIS concept based on the NIS concept created by Lundvall (2007), who separates NIS's boundaries as the core and the wider setting. The core of innovation system, a narrow definition, is the interaction between the knowledge exploration subsystem and the knowledge exploitation subsystem. The former includes universities, research institutes, technology extension centers, and labor market mediating organizations, producing knowledge and technologies to support regional industries. The latter refers to firms located in one or several clusters, which interact with one another and with knowledge-producing organizations to exploit new knowledge to improve their innovative performance. The wider setting, which is a broad definition, includes innovation-related policies that help build competencies of both individuals and organizations and promote interactive learning and innovation from the interaction between users and producers. Those policies include education and training, labor market, financial market, and public policy, stimulating innovation and firm capabilities.

2.4 Conceptual Framework of NIS in the Developing Country Context

Most NIS in developing countries can be conceptualized as emergent or fragmented innovation systems. In these systems, economic actors and institutions still exist, but their linkages are still in formation, and their competencies are still low (Chaminade et al., 2010). Cirera et al. (2017) found that the innovation paradox happens in three main dimensions. First, firms in developing countries have a low or even a negative return on R&D investment when they are further from the frontier countries because they lack significant complementary factors to R&D activities. Second, even though managerial and organizational capabilities are essential for firms to manage the adoption and development of new technologies, they do not initiate their effort themselves to upgrade their capabilities. Third, since developing countries have a lower level of complementary factors than developed countries to support their firms, the scope and magnitude of their NIS are more complex than the latter; however, their government capabilities are weaker. These problems require developing the NIS conceptual framework to resolve the specific economic and social challenges in developing countries.

To resolve the systemic problems in the context of developing countries, Maloney (2017) proposed an "expanded NIS" (figure 2.1), created from the reconciliation of the neoclassical economic model and NIS approach. Considering the institutional changes in its analysis, the neoclassical economic model narrows its gap with the NIS approach. Furthermore, both approaches recognize the importance of both market mechanism and market failure approach. NIS approach still addresses the market failure approach through innovation policy, but it changes its focus from R&D capabilities to managerial capabilities in developing countries at the early development stage. In addition to R&D activities, the complementary factors, such as physical capital, human capital, and managerial capabilities, should also be incorporated into the analysis of the NIS's boundaries.

Figure 2.1 Expanded National Innovation System Concept



Source: Maloney, 2017

In developing countries, the boundaries of NIS should address both the barriers to the accumulation of knowledge and all types of capital. The former incorporate inflexible labor regulation, lack of seed or venture capital, and inability to exploit the innovation externalities. The latter incorporate an inconducive credit market, entry and exit barriers, unfavorable business and regulatory climate, and weak enforcement of the rule of law. Policymakers should provide firms with incentives to upgrade their capabilities by promoting a conducive macro-economic and competitive environment, providing good trade regimes, and supporting international networks. So, the common problem of a low level of innovation in developing countries depends not only on the traditional NIS but also on the organizations and institutions to improve the general business environment.

2.4.1 Demand Side of NIS

Management and production capabilities are the first level of the three capabilities escalator: management and production capabilities, technology adaptation and imitation capabilities, and invention and technology-generation capabilities. In developing countries, management and production capabilities are the central unit of NIS analysis at the early development stage rather than R&D activities as they are the major complementarity factor to innovation investments in the innovation process and represent the most crucial element of the demand side of the NIS. When firms in developing countries lack management capabilities, they cannot define technological opportunities, create long-term plans to exploit them, and cultivate the human resources to execute them. This may be the reason to explain why developing countries have a small number of firms investing in foreign technology licenses, internationally-recognized certification, machinery and equipment, and R&D activities to produce new products and processes. Cirera et al. (2017) explained that there is complementarity between production factors because the innovation-related investments increase in parallel with economic development. For example, when a firm or a country wants to increase innovation investments, it also needs to invest in machinery and equipment, trained people, and organizational techniques.

Managerial practices have a significant impact on firm productivity and vary across firms and countries. Bloom et al. (2012) used a double-blind survey, in which interviewers do not know the performance of sample firms, and the respondents do not see that they are interviewed to evaluate their management practices. They randomized the sampling of 10,000 firms with employees between 100 and 5000 operating in manufacturing, retails, hospitals, and schools. The result shows that firms and organizations in developed countries are better managed than those in developing countries. The study also found that management practices also vary across firms within the countries, reflecting a significant variation of productivity and profitability across firms within industries.

Managerial practices help improve firm productivity of lower-income countries and lower-tech sectors than higher-income countries and higher-tech sectors. Bartz et al. (2016) used the firm-level innovation survey data between 2011 and 2014 on 30 countries from Eastern Europe and Central Asia. They used the CDM model developed by Crépon, Duquet, and Mairesse (1998) to identify the relationship between management practices, innovation, and labor productivity. The result shows that returns on management practices and innovation improve firm productivity in developing countries. However, the former has a higher impact on firm productivity than the latter in lower-income countries. In higher-income countries, firms have a higher return on innovation than the return on management practices. In the same vein, the return on management practices is higher in the lower-tech sector, while the return on innovation is higher in the higher-tech sector.

Managerial practices can be improved by using both internal and external sources. According to Bloom et al. (2012), several internal factors can explain the change in management practices across firms or organizations. Most organizations that are owned and managed by the government are poorly operated. However, multinational firms and firms with dispersed shareholders and private equity are always well organized. Moreover, family-owned firms managed by professional CEOs are still better operated than those organized by family members. Firms that are owned and managed by founders are the most poorly operated. Besides, product market competition is a factor that forces lower performers to exit the market or to motivate survivors to upgrade management practices to compete in the product market. While educated managers and workers are associated with acceptable management practices in general, light labor regulation promotes the improvement of management practices specifically.

On the other hand, domestic firms can also learn to upgrade their management and production capabilities, from external sources, including international trade participation, link to MNCs, and participation in the global value chains (GVC). Sole exporters and two-way traders can learn to adapt the quality of their products to the standard of the global markets and get incentives to learn by facing direct competition with or exposure to international firms. Simultaneously, sole importers can access new knowledge and technologies embedded in the equipment and machinery or inputs when importing them. Domestic firms may access new experiences and technologies from MNCs through direct observation, direct competition, and skilled employees sourced from them. Through these technology transfer channels, developing countries can promote backward and forward linkages with multinational firms to gain a spillover effect (Cirera et al., 2017).

However, domestic firms need to have the necessary competencies to gain potential benefits from participation in GVCs. To understand how the innovation system can help domestic firms move up the GVCs and become the lead firms in the GVCs, Pietrobelli et al. (2010) used GVC governance forms introduced by Gereffi et al. (2005) for their study. Those forms include market, modular, relational, captive, and hierarchical ones. In modular form, lead firms may put pressure on domestic suppliers to produce products adapting to international standards. In captive one, lead firms are involved in the local suppliers' learning mechanisms due to their limited production capabilities. In relational form, both lead and local firms have complementary capabilities to support each other, so they have face-to-face interactions to develop innovations.

The market form applies market transactions for exchanging goods and services, but the hierarchical one uses a pure organizational structure to manage the learning process and exchange of goods and services. However, some problems have occurred through these learning processes. For example, in relational form, local suppliers can access only the knowledge of production capabilities but cannot access the design and planning capabilities. Moreover, in captive form, lead firms provide only technological knowledge related to the assembly line to local suppliers but still prevent their core competencies.

As the solutions to the above problems, a well-structured and effective innovation system can transform the GVC governance forms into the market or the GVC governance of less hierarchical forms (Pietrobelli et al., 2010). For example, a system of organizations supporting metrology, standards, testing, and quality reduces the complexity of transactions, so it helps to transform from captive and hierarchical forms to market, modular, and relational forms. Similarly, a system of innovation supporting competence building and firm capability upgrading can help transform the GVC governance from captive and hierarchical forms into modular and relational ones and facilitate the learning process so that domestic suppliers can move up the GVCs. They may become the lead firms organizing GVCs later. The next subsections will show how the government can initiate programs supporting competence building and firm capability upgrading.

2.4.2 Supply Side of NIS

Management capabilities, which can be improved through SME information and advice support services, are limited in developing countries than in developed countries. Market failure can be analyzed to understand the rationale of the government support in SME information and advice support services to upgrade firms' management capabilities. According to European Commission (2002), four forms of market failure are identified. First, adverse selection occurs when both providers and consumers of business support services have a different level of information, incomplete information, or inaccurate information, leading to discontinuities in information exchange. Second, business support services, especially information needed by SMEs, might not be provided privately since the private sector firms cannot sufficiently earn a return on their investment. In this case, the information should be treated as “public goods” and thus should be provided by the public sector.

Third, when SMEs have substantive needs for information and advice services, the private sector cannot provide these services at a commercial price. In this case, the “mixed goods” approach should be applied to offer information and advice services for specific groups or all SMEs but with a non-commercial price. Fourth, when an exchange transaction between provider and consumer occurs, it has an externality on other SMEs. If the externality is positive, it should be promoted. On the other hand, if the externality is negative, the appropriate “guidelines” and rules should be developed to manage its broader harmful effect on other SMEs. Understanding the market failure applied in the provision of SME information and advice support services, the government could create the rationale and design of the public interventions. However, it can successfully implement public support to management and production capabilities if its capabilities are good.

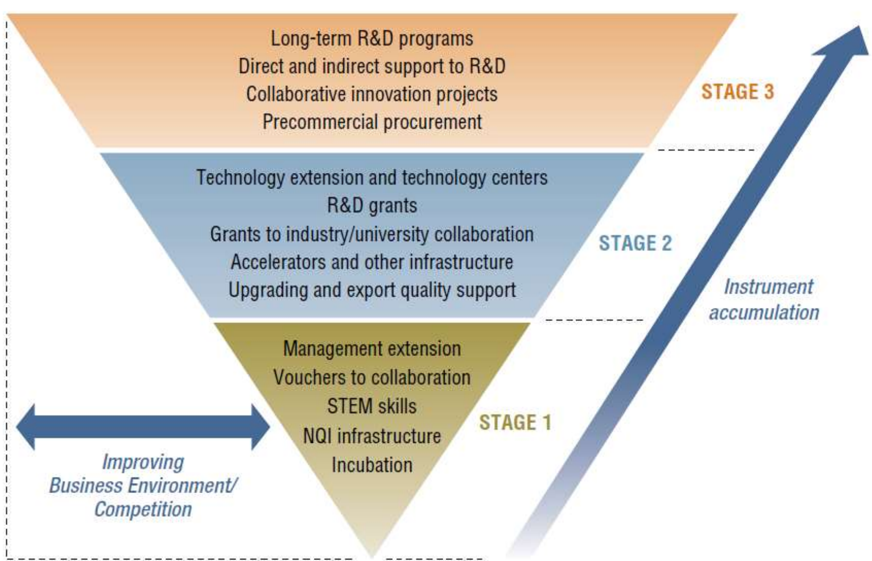
In contrast, governments in developing countries have limited capabilities when the scope and complexity of their interventions increase (Cirera et al., 2017), leading to the innovation paradox. To resolve this problem, the government needs to reduce the demand for government capabilities to support firm capability upgrading by accumulating innovation policy instruments on various economic development stages. According to Cirera et al. (2017), the set of innovation policy instruments should have been accumulated when firm capabilities, government capabilities, and the business environment have been improved (figure 2.2). Since firm capabilities are different at different stages of the capabilities escalator, it is awkward for the innovation policy that only focuses on the development of R&D projects at the high-end part of the capabilities escalator before developing management extension and technology extension services in the first two stages.

Management extension services should be designed based on the result of analysis of four forms of market failure. These services should be committed to implementing to enhance the management capabilities at the national level. As management capabilities have been improved for the critical mass of domestic firms, the demand for technology extension services and R&D activities also increases. These domestic firms will start to invest in the knowledge production process to upgrade their technological capabilities in the new techno-economic paradigms.

Then, developing countries will move to the second level of capabilities escalator and play a role as a proactive state. The proactive state is an emergent concept for policymaking and implementation. It develops and coordinates mission-oriented policies to pursue and resolve the grand societal challenges. It can also design innovation policy by applying four functions: directionality, demand, reflexibility, and coordination (Chaminade et al., 2018). In directionality, the government needs to forecast new technologies used in the new techno-economic paradigms for orientating the private sector to invest in them while taking risks by investing in R&D activities in the latest technologies to support R&D investments of the private sector. In demand articulation, it needs to consider the demand for new technologies by anticipating user needs and adopting public procurement strategies. Reflexibility articulation refers to agents' ability to anticipate changes and mobilize the critical mass of actors to invest in these innovation activities to capture large national and international markets of these new technology products. Coordination articulation refers to the need to coordinate the innovation-related policies, including education and training, labor market, science and technology, industry, and trade, to pursue innovation potentials in the new techno-economic paradigms.

Remarkably, since technological capabilities and advanced R&D capabilities need decades to gain significant impacts, they should also be started at the early stage of the capabilities escalator but with a small scope and scale of the particular needs of the science-based industries and radical innovations. This implication is in line with World Bank (2010), which shows that countries with good knowledge endowments and good institutional climate can develop frontier technologies and diffuse them to their private sector. However, developing countries with small knowledge endowments and weak institutional environments need to absorb and adapt globally available new technologies into the local context before diffusing them into the broader economy. Also, frontier technologies should be explored in the amounts in need.

Figure 2.2 The Capabilities Escalator: The Policy Mix Evolves from Less to More Sophistication



Source: Cirera et al. (2017)

This new approach suggests that policymakers create a new path of innovation system to develop new technologies in the new techno-economic paradigms. While the evolutionary perspective addresses the time sequencing of the path creation process, the systemic perspective suggests the government intervene in establishing or breaking the interactions between users and producers in the innovation process to promote path creation in the new technologies. In this manner, the government needs to support the competence building for both users and producers and promote the linkages between them to make the latest technologies successful. Similarly, Fagerberg et al.

(2015) also suggested mission-oriented policies to cope with the grand societal challenges. They indicate that NIS needs to be carefully evaluated to identify systemic problems and propose the appropriate selective innovation policies to develop new technologies in the new techno-economic paradigms.

To implement innovation policy effectively, government, particularly innovation agencies, needs to improve the following four dimensions (Cirera et al., 2017). First, policy design needs to be developed to address diagnosed market failures rather than mimic the foreign institutional framework. Second, the efficacy of implementation needs to be assured by adopting efficient public management practices suitable for the context of developing countries and using monitoring and evaluation tools to evaluate, adapt, modify, or sometimes terminate any policies when necessary.

Third, the policy's coherence needs to be attained by improving the ability to review the overall system and coordinate various innovative policies managed by multiple ministries or organizations. These different organizations in developing countries always balkanize these policies. These organizations' missions are not clear-cut, and their stated goals are not aligned with their actual budgets and impacts. Fourth, policy consistency and predictability are necessary for institutions to implement their innovation policies successfully. They need to commit their financial resources to implement their innovation activities over a more extended period to realize the real economic and social impacts. Usually, the innovation agenda in developing countries is often overlooked by policymakers, especially by a high-ranking political leader. Hence, most innovation institutions lack long-term financial support to implement innovation policies to realize their stated goals.

2.4.3 Transformation of NIS

Chaminade et al. (2010) classified NIS into three stages of economic development: emergent innovation systems in low- and lower-middle-income countries, fragmented or dual innovation systems in upper-middle-income countries, and mature innovation systems in high-income countries. However, this classification of innovation systems is static. Chaminade et al. (2018) proposed a dynamic framework similar to the framework developed by Cirera et al. (2017) to explain the evolution of the three-stage innovation systems. Over time, the form of an emergent innovation system can evolve to become the mature one. Sometimes, the mature innovation system evolves to become a fragmented or emergent innovation system, depending on the match between the institutional framework and the need for the particular industries' innovation activities.

Low- and lower-middle-income countries need to build citizens' competencies and firm capabilities to transform themselves to become an upper-middle-income country. They are characterized as an emergent innovation system which suffers from lower education level, lower wage, and depends only on the export of primary products (Chaminade et al., 2018). As a result, they tend to fall into the poverty trap. To release from the poverty trap and move to become an upper-middle-income country, they need to build citizens' competencies. They also need to attract foreign direct investments in new industries to promote structural transformation and learn to imitate existing technologies brought from abroad. Management capabilities, which are the first level of capabilities escalator, are the central unit of NIS analysis to upgrade to transition to the next level of capabilities escalator. According to Lee (2013), to become an upper-middle-income country, latecomers should try to develop their firm capabilities by exploiting learning channels such as licensing, contracted patents, and FDI in original equipment manufacturing (OEM). The policymakers can promote these learning processes through adopting and implementing a trade-based industrial policy focusing on tariffs, devaluation of the currency, and entry control.

However, Choi et al. (2019) suggested that countries characterized as innovation followers rely on importing foreign technologies and foreign direct investments. The government needs to provide the incentives to promote entrepreneurial activities and business creation while upgrading firms' necessary competencies to absorb foreign technologies and management practices and adapt them to the local context. With these upgraded firm capabilities, they also can gain technology spillovers from FDIs. This way, they can balance their knowledge production and knowledge application processes and reach the next level as the innovation application leaders. Tödtling et al.

(2005) analyzed the peripherical regions as the emergent innovation systems. The peripherical regions are characterized by low levels of R&D and innovation, weakly developed clusters of firms, a small number of knowledge providers, and weak institutional set-ups to support innovation. The policy-makers need to strengthen the capabilities for "catching up learning." They need to take adequate policy measures to attract multinational firms to enter their regions. While connecting their firms with external clusters and the knowledge providers, they need to link the firms with the broader level of innovation systems (national and European Union levels).

Middle-income countries need to develop technological capabilities by strengthening technology extension services, while management capabilities and competence building still need improvement. These countries are classified as fragmented innovation systems that also face development challenges such as increasing salaries, lacking the skilled labor force, and relying on the exports of some specialized products (Chaminade et al., 2018). These challenges may lead them to fall into the middle-income trap. If they are willing to go beyond the middle-income trap, they need to pursue the structural transformation into new industries. According to Lee et al. (2018), to sustain the catch-up process and avoid the middle-income trap, latecomer firms need to enhance their firm capabilities and find market niches in short-cycled technology sectors and shift from endowment-based specializations to technology-based specializations. In this sense, latecomers need to promote domestic firms to develop in-house R&D activities as they cooperate with foreign firms or public research institutes (Lee, 2013). Also, they can create R&D outposts abroad, such as the Silicon Valley in California, to learn new technologies. They also need to adopt a technology policy to develop public-private R&D consortia targeting short-cycled technology sectors, entirely unknown to incumbent countries.

Similarly, according to Choi et al. (2019), countries characterized as knowledge application leaders could build their knowledge production processes by encouraging R&D cooperation between industry and academia to enhance their technological capabilities and R&D capabilities to become innovation leaders for the next step. According to Tödling et al. (2005), in metropolitan regions characterized as fragmented innovation systems, the capacities of both knowledge exploration subsystem and knowledge exploitation subsystem are strong. Still, their interaction is weak, making them function separately and not match with each other. To cope with the fragmented innovation systems, they need to encourage communication and interactive learning between firms and knowledge providers. Thus, the public authorities need to develop the internationally linked knowledge-intensive sectors, promoting science-based and radical innovations.

Lee et al. (2018) initiated a long-term detour as a development path to propose latecomers leapfrog from low-end segments to high-end segments, short-cycled technologies. Latecomers can capture windows of opportunities such as technological opportunities, new demand, and unique institutional setting or public policy along this detour. Technical opportunities occur when new technological paradigms emerge. These new technologies require technological and organizational capabilities, which may also benefit small new innovative firms. Firms can also target local low-cost market demand such as Nano cars in India and Lilipit computers in China by absorbing existing available technologies from abroad and adapt them to the local context. Institutional set-ups conducive to technological changes in latecomers can provide them with opportunities to promote new technologies and catching up. These opportunities can co-evolve or evolve separately.

For developed countries, they need to invest in long-term R&D projects to support private firms (Cirera et al., 2017). However, they also face the problem of lock-in in the old technologies if they don't develop the linkages with global innovation networks to be alert to the changes of technologies and demand in the world market (Chaminade et al., 2018). Similarly, the old industrial regions are characterized by a critical mass of innovative firms, dominant firm clusters, and adequate innovation supporting organizations. However, they intensely concentrated only on old industries and old technology trajectories (Tödling et al., 2005). This lock-in situation may derive from the strong connection between the enterprises and the public agencies, the cognitive blockade due to the common world views, too narrow orientation of the knowledge providers on only old technology trajectories. Public authorities need to renew the old industries by supporting the innovative activities in those industries and the related ones and upgrading the knowledge base to support them. They should orient the policy measures to reorganize firms, networks, and institutions to promote industrial and technological diversification.

2.5 Conclusion

As shown above, developing and developed countries are characterized by different contexts in terms of the NIS framework. Developed countries have such a conducive business environment that they have accumulated adequate complementarity factors and their national innovation systems may focus only on promoting R&D activities in the private sector. However, this is not the case for developing countries. They have a low level of R&D activities because they lack adequate complementarity factors to innovation, such as physical capital, human capital, and management capabilities. In this sense, the boundaries of the NIS should be expanded beyond the traditional concept, in a view to address barriers preventing the accumulation of knowledge, as well as those concerning all the complementary types of capital. The former barriers include labor market rigidities, the lack of seed or venture capital, and the inability to exploit the innovation externalities. The latter barriers include inconducive credit market, entry and exit barriers, limitations of the business and regulatory climate, and a weak enforcement of the rule of law. Domestic firms' incentives to invest in the innovation activities include also favourable macroeconomic and competitive contexts, good trade regimes, and international networking. The capabilities escalator is classified into three stages: management and production capabilities, technology adoption and absorption capabilities, and invention and technology generation capabilities. Low- and lower-middle-income countries are characterized as emergent innovation systems. Thus, management capabilities and citizens' competencies are the central units of analysis because they are the most critical complementary factors to innovation, as the general business environment is still poor. When they move to become an upper-middle-income country, they are characterized by fragmented or dual innovation systems. At this level, technology adoption and absorption capabilities become the central unit of analysis, as the management capabilities and competencies of citizens still need to be upgraded. Finally, when they move to the next level – mature innovation systems, invention and technology generation capabilities become the central unit of analysis. However, the first two levels of the capabilities escalators often still need to be upgraded. This evolution of national innovation systems implies that policymakers should carefully evaluate and identify their countries' initial levels before adopting selective innovation policies to upgrade their NIS.

Chapter 3: Upgrading the National Innovation System in a Late-Industrializing Country, Cambodia

3.1 Introduction

The government has set a goal to transform Cambodia into an upper-middle-income country in 2030 and a high-income country in 2050 (RGC, 2018). According to World Bank (2018d), the upper-middle-income country target will be achieved a bit late in 2035, while the high-income country target can be reached on schedule. To achieve these goals, Cambodia needs a structural transformation from agriculture to industry and services. Also, it needs a resource reallocation within each sector by moving human and physical capital from low to higher value-added sectors. This transformation implies an improvement in total factor productivity, in a view to promote sustainable economic growth. Innovation is recognized to play an important role in spurring economic development. However, even though Cambodia has an improved business environment, it still has limited innovation capabilities, compared to neighboring countries like Thailand and Vietnam. If Cambodia wants to upgrade these capabilities, the problems of its national innovation system have to be understood and solved. The NIS concept presented in Chapter 2 can be used to analyze the Cambodian economic situation and identify its main systemic issues.

Chapter 3 aims to analyze Cambodia' NIS to identify its problems and possible solutions, using the expanded concept of NIS proposed in Chapter 2. Cambodian NIS stays at the early stage of the capabilities escalator as an emerging innovation system. Even though business environment has been improved significantly, it is still not conducive to promote firms to perform innovative activities. The macroeconomic and competitive contexts can help promote innovative performance. However, physical and soft infrastructures still represent a high cost of doing business and high trade costs, which prevent Cambodian firms from integrating into international markets, regional value chains (RVCs), and global value chains (GVCs). Business regulations are still burdensome, impeding informal firms to become formal ones. The complementary factors to innovation, including human capital, financing, business development services, are still challenging to upgrade firm capabilities.

The low level of these complementary factors can explain why Cambodia has a low level of innovation performance. Management capabilities and citizens' competencies, representing the demand side of NIS, are still limited in Cambodia, which the supply side of Cambodian NIS should treat as central units of analysis to provide the public interventions. These interventions can mobilize the critical mass of medium-sized exporters, innovative local suppliers, startups, and tech SMEs, which will increase the R&D activities to upgrade their technological capabilities. The increase in R&D will become the demand side of the R&D activities supplied by universities and public research institutes. This way, Cambodian NIS can be upgraded into the next level of capabilities escalator, maturing NIS.

This chapter will be organized as follows. In section 3.1, macroeconomic performance and framework conditions for innovation will be identified by focusing on factors promoting firm capability upgrading. Those factors include macroeconomic context, infrastructure, business regulations, human capital, access to finance, business support services. Section 3.2 focuses on the national innovation performance. In section 3.3, innovation needs will be better understood by studying how the Cambodian firms integrate into the international markets and the regional and global value chains. The NIS supply side will be analyzed in section 3.4, which focuses on national education and training system, business support system, and domestic and international science and technology system. Section 3.5 will conclude.

3.2 Macroeconomic Performance and Framework Conditions for Innovation in Cambodia

To achieve the vision of becoming an upper-middle-income country and a high-income country on schedule, Cambodia needs to increase the investment rate from 22% of GDP in 2017 to 28.5% of GDP in 2030 and maintain the pace until 2050. With the current saving rate of 13% of GDP, Cambodia needs to promote additional domestic savings up to 10% of GDP, in which 6% for absorbing the rising investment rate and the other 4% for offsetting the decreasing rate of foreign savings (World Bank, 2018d). Cambodia needs to promote structural transformation from agriculture to industry and services and do it within sectors by moving human capital and physical capital from low to higher value-added sectors. While traditional industries are still important, the diversification strategy should be targeted into new industries beyond successful activities. To achieve this objective, Cambodia also needs to improve the business and investment climate, such as access to finance, contractual enforcement, human capital, while developing adequate selective policies and regulatory frameworks to promote both domestic and foreign direct investments. The digital economy should also be prepared to accelerate economic development and diversification since it can help create new jobs and develop the existing and new manufacturing industries to compete in the regional and world markets (te Valde, 2019).

Even though Cambodia tries to improve the business environment to promote economic diversification and development, macroeconomic performance and framework conditions still show some challenges to support the national innovation performance. The macroeconomic context is stable, promoting both domestic and foreign direct investment in existing and new industries. However, physical infrastructure still needs to be improved to reduce the importing and exporting costs and increase ICT adoption, which can help domestic firms link to the regional and global value chains and international markets. Business regulations are still not conducive to promoting informal firms to become formal ones and encourage firms to export or participate in the regional and global production networks, resulting in missing the middle of the export structure. Financing is still not relevant to the firms' innovative projects since Cambodia relies on traditional financial services rather than risk capital and innovative financial services. Human capital represents significant challenges in upgrading the skills of the current workforce and future ones. The following subsections will discuss each of the framework conditions in turn.

3.2.1 Macroeconomic Context

Macroeconomic context has been recognized to promote domestic and foreign firms to enter into businesses. It is also necessary to encourage firms to expand operations, increase capital investment, provide staff training, hire qualified human resources, purchase management extension services, and perform innovation activities to upgrade their firm capabilities. Cambodia seems to have improved the macroeconomic performance since it ranks 75th of 141 countries in macroeconomic stability, not significantly weaker than the neighboring countries, Vietnam (64th) and Thailand (71th) (WEF, 2019) (see Table 3.1).

Table 3.1 Rankings and Scores of Global Competitiveness Index 2018 of Cambodia, Thailand, and Vietnam

Indicators	Cambodia		Thailand		Vietnam	
	Score	Ranking	Score	Ranking	Score	Ranking
Overall Score of Competitiveness	52	106	68	40	62	67
Macroeconomic Stability	75	75	68	71	75	64
Infrastructure	55	106	90	43	66	77
ICT Adoption	55	71	60	62	69	41
Domestic Competition	46	107	54	65	54	64
Financial System	56	88	85	16	64	60
Skills	43	120	62	73	57	93
Innovation Capability	31	102	44	50	37	76
Research and Development	18	121	34	56	25	72
Trade Openness	51	115	53	99	54	91
State of Cluster Development	48	64	51	47	53	44
Entrepreneurial Culture	50	76	57	33	50	68
Quality of Research Institutions	00	117	12	43	4	58
Multi-Stakeholder Collaboration	44	82	52	40	44	80

Source: World Economic Forum, 2019

Productivity gains may partly explain the above growth rate. The productivity growth of 6% is the largest contribution to the growth of per capita value added of 4.26% in 2007-2014 (World Bank, 2017a, 20-21). However, the agricultural employment rate fall leads to a decrease in per capita value added by 2.8%. The fastest annual productivity growth derives from real estate at an average yearly rate of 2.7% in 2007-2014, followed by agriculture and trade at 1.86% and 0.7%, respectively. Labor productivity is still low compared to other comparator countries. Cambodia experienced the labor productivity growth rate at 3.5% in 1994-2014, lower than Vietnam at 4.7% in the same period and Thailand at 7.1% during the booming years of 1986-96. Remarkably, the labor productivity of garments in Cambodia is still lower than in comparator countries, and this may derive from lower investment in machinery and equipment in Cambodia.

Table 3.2 Balance of Payments, 2011-20 (USD million)

Main Components	2013	2014	2015	2016	2017	2018	2019	2020
Current Account Balance	(1,295.71)	(1,444.10)	(1,598.45)	(1,733.54)	(1,807.05)	(2,895.13)	(4,067.02)	(3,056.86)
Goods and Services, net	(1,932.61)	(2,126.40)	(2,236.51)	(2,244.08)	(2,414.43)	(3,447.99)	(4,445.11)	(3,694.33)
Goods, net	(3,635.75)	(3,853.45)	(3,948.84)	(3,846.49)	(4,275.11)	(5,839.91)	(7,253.42)	(3,566.94)
Exports	7,043.87	8,168.54	9,336.30	10,272.93	11,229.06	12,973.30	14,997.97	17,406.91
Imports	10,679.62	12,021.99	13,285.15	14,119.42	15,504.17	18,813.21	22,251.39	20,973.84
Services, net	1,703.14	1,727.05	1,712.33	1,602.41	1,860.68	2,391.92	2,808.31	(127.40)
Receipts	3,493.72	3,810.81	3,954.73	4,032.91	4,606.61	5,447.82	6,083.11	1,933.36
Payments	1,790.58	2,083.76	2,242.40	2,430.50	2,745.93	3,055.90	3,274.80	2,060.76
Income Balance	(825.09)	(931.18)	(998.04)	(1,050.32)	(1,140.67)	(1,327.72)	(1,564.21)	(1,010.32)
Credits	265.24	332.33	353.73	377.03	441.88	579.96	732.34	665.96
Debits	1,090.32	1,263.52	1,351.77	1,427.34	1,582.56	1,907.68	2,296.55	1,676.28
Current Transfers	1,461.99	1,613.48	1,636.10	1,560.86	1,748.05	1,880.58	1,942.31	1,647.80
Credits	1,584.51	1,755.30	1,759.55	1,740.87	1,893.76	2,018.34	2,075.52	1,748.46
Debits	122.52	141.82	123.45	180.01	145.71	137.76	133.22	100.66
Capital Account Balance	314.95	268.14	265.13	283.31	278.52	325.79	355.15	258.14
Current and Capital Account Balance	(980.75)	(1,175.97)	(1,333.32)	(1,450.23)	(1,528.54)	(2,569.34)	(3,711.87)	(2,798.72)
Financial Account Balance	(1,458.70)	(1,093.46)	(1,846.11)	(1,745.74)	(1,764.35)	(2,207.33)	(3,695.67)	(3,205.70)
Direct Investment, net	(2,006.20)	(1,771.41)	(1,735.04)	(2,396.84)	(2,672.11)	(3,088.36)	(3,560.88)	(3,484.81)
Direct investment abroad	62.27	82.06	87.76	79.07	114.87	124.06	101.94	126.63
Foreign direct investment	2,068.47	1,853.47	1,822.80	2,475.92	2,786.98	3,212.42	3,662.81	3,611.44
Portfolio Investments, Net	18.79	22.53	14.67	2.09	5.48	42.01	12.41	95.84
Other Investments, net	166.10	(99.33)	(956.46)	(223.55)	(729.51)	(606.28)	(2,823.49)	(451.91)
Net financial assets	1,303.75	117.66	(102.91)	675.19	185.20	513.45	(180.86)	2,190.61
Net liabilities	1,137.65	217.00	853.55	898.75	914.71	1,119.74	2,642.63	2,642.51
Reserve Assets	362.61	754.75	830.72	872.56	1,631.78	1,445.30	2,676.29	635.17
Net Errors and Omissions	(477.94)	82.51	(512.79)	(295.51)	(235.82)	362.01	16.19	(406.98)

Source: National Bank of Cambodia, 2021

The current account deficit is financed mainly by FDI inflows (Table 3.2). The current account deficit reached a maximum of $ 4 billion in 2019 before decreasing to around $ 3 billion afterward (NBC, 2021). This reduced deficit derives mainly from a slight decline in import growth and expanding export growth (primarily in garments) in recent years and by positive earnings in tourism sectors and remittances from emigrated workers. Remarkably, Cambodia has experienced substantial repatriation of income abroad. As a result, the foreign exchange reserve increases up to $ 635 million in 2020.

International trade is essential for Cambodia as the incentives and the sources of learning to upgrade firm capabilities. The proportion of trade in goods and services has increased from 127% of GDP in 2011 to 140% of GDP in 2016. Cambodia dominantly exports clothing, and it imports textiles to produce clothing. According to te Valde (2019), the European Union and the United States have become a dominant market share of Cambodia's exports since only five countries from both regions represent around 50% of total exports. On the other hand, Cambodia imports mainly from Asia with nearly 90% of total imports.

Garment exports, which focus only on low quality/low price segments of the US and EU markets, represent almost 70% of total exports. However, some garment factories recently started to move up the value chains by investing in embroidery, washing, and printing activities. Even though new industries such as bicycles, television parts, and ignition wires emerge as higher value-added products, they operate only as of the assembly process, which is at the early stage of regional value chains. According to the World Bank (2017c, p. 17-20), non-textile exports excluding footwear have increased from 2% in 2010 to 8.7% of total exports in 2016. Cambodian Special Economic Zones (SEZs) have been seen as a policy tool to promote diversification into new industries. Among 75 manufacturers in Phnom Penh Special Economic Zone (PPSEZ), only seven are operating in apparel and clothing. Japanese investors are the keenest to invest in SEZs, followed by other investors from Asian countries. These firms may be part of the regional or global value chains. PPSEZ has 41 Japanese firms among all firms, and the other three firms are joint ventures between Cambodian firms and Japanese firms. The first arrived in 2008, followed by half of the total firms in PPSEZ arrived only for the last two years.

Even though the tourism sector represents almost 70% of the services sector, it also challenges further diversification within the sectors due to the declining external competitiveness by US dollar appreciation, rising wages, and environmental sustainability constraint.

FDI inflows are the sources of knowledge spillovers for domestic firms to upgrade firm capabilities. They have increased for the last decade. According to ITC (2021), FDI inflows increase to $ 3.1 billion in 2020, thanks to the liberal and investor-friendly climate. The FDI stock from China were at 29% (Table 3.3). Most of the ASEAN investments are from multinational firms located elsewhere in ASEAN, such as Singapore. Still, they invest as an affiliate in Cambodia to supply some parts or components for other ASEAN affiliates. Other main investment partners include Hong Kong, China, the Republic of Korea, Chinese Taipei, and Japan. On the other hand, the EU and the USA, which invest substantially in ASEAN countries, are less represented in Cambodia. The aggregate capital formation is less than 20% of gross domestic product (GDP) per year in the past two decades, much lower than in Thailand and Vietnam (World Bank, 2017b).

Table 3.3 FDI in Cambodia by Source Country, 2011-18 (USD million)

	2011	2012	2013	2014	2015	2016	2017	2018	Stock	
China	180	368	287	554	538	502	629	811	6812	29%
ASEAN	224	523	299	372	425	636	602	764	6308	27%
Hong Kong, China	48	92	83	136	138	249	347	349	1688	7%
Korea, Republic of	139	162	178	106	72	140	177	250	1934	8%
Japan	22	14	38	85	52	199	226	199	1589	7%
EU	54	126	115	144	188	202	215	168	1405	6%
Taipei, Chinese	109	173	173	122	76	98	169	122	1629	7%
Canada	6	5	-7	4	15	26	69	101	353	1.5%
USA	17	16	34	50	41	53	74	59	494	2%
Australia	20	23	19	33	32	35	32	20	214	1%
Other	72	56	55	118	123	140	189	234	819	3.5%
Total	892	1557	1275	1726	1701	2280	2731	3076	23246	

Source: International Trade Center (2021)

3.2.2 Infrastructure

Infrastructure is critical for firms to reduce the cost of doing business by accessing reliable electricity and water at reasonable prices and the transport system. The latter's improvement also reduces exporting costs to participate in international trade and global value chains (GVCs). This international integration provides the incentives and knowledge sources to upgrade Cambodian firms' products into higher value-added segments in GVCs or diversify into new industries. Cambodia appears to have the inadequate infrastructure to support their firms to integrate with GVCs and international markets since its rank is 106th among 141 countries in the infrastructure index in the global competitiveness index (GCI) 2018 (Table 3.1), which is significantly lower ranking than Thailand (43th) and Vietnam (77th).

Even though firms perceive the improvement in electricity and transport infrastructure by observing the lower ranks of the list of the main constraints, they are still among the top ten constraints. According to te Velde (2019), only 51% of the total population can access electricity, and its price is 35% higher than in Thailand, Vietnam, or Myanmar. On the other hand, the multi-modality transport infrastructure still needs to be improved to reduce transport costs, which is the main cost of firms participating in the regional and global value chains (OECD, 2018a).

Cambodia has the vision to develop itself to become a digital economy; thus, ICT network infrastructure and mobile banking are critical for Cambodian firms to adopt digital transformation and to link themselves to the global supply chains. Cambodia's ICT network is good, even though it still needs further improvement. According to World Bank (2018b), mobile broadband subscriptions increase above the regional average at 125 per 100 inhabitants. Still, fixed-broadband subscriptions remain low at 0.6 per 100 inhabitants in 2016, well below the regional and world averages. Finally, most mobile broadband subscriptions use only 2G and 3G services, while 4G service coverage is still limited.

On the other hand, cash economy culture is more common than cashless transactions since Cambodia lacks a national payment system as an e-payment gateway to promote electronic money payment (UNCTAD, 2017). In logistics and trade facilitation, large logistics firms compete with MSMEs in the "last mile" delivery, especially in the urban market. Also, trade facilitation has been improved to adapt to the regional standard and international best practices.

3.2.3 Business and Regulatory Climate

Business regulations play an essential role in promoting domestic firms and foreign firms to start and operate their businesses. Cambodian firms still confront many constraints on the business environment's various variables, which are the barriers to impede businesses from operating efficiently. Cambodian SMEs have significant constraints in starting and operating their businesses (EMC, 2017). First, Cambodia ranks 180th of 190 countries in 2016 in ease of starting a business. Firms need to complete six procedures to start their businesses and spend up to 99 days to complete the business registration process. Second, 7.8% of registered firms perceive tax rates as a major constraint, while 3.6% perceived tax administration as a major constraint. Third, firms need to spend up to 173 hours per year to prepare and file necessary documents to pay major taxes. Fourth, a third of exporters perceived customs and trade regulations as the major constraints, while only 3% can access information related to customs and trade regulations. Fifth, Cambodia ranks as 178th of 190 countries in the enforcement of a contract. Firms need to spend time up to 483 days to finalize contract enforcement in the Cambodian court system, while the cost of legal process may be higher than the value of a claim. Finally, corruption is still a major problem since 10% of businesses report it as a significant constraint.

Cambodia can be characterized as a "missing the middle" economic structure since most SMEs are small and informal. When informal firms perceive the cost of becoming formal firms higher than their current status, they tend to stay informal. For instance, most Cambodian MSMEs decide to stay informal because they can avoid tax administration burdens and licensing issues (OECD, 2018a). EMC (2017) argued that informal firms face fewer constraints than formal firms in business regulations, making them decide to stay informal. The business regulations include business licensing and operating permits, customs and trade regulations, regulatory policy uncertainty, tax rates and tax administration, corruption, business conflicting and resettlements, and anti-competitive and informal practices. Besides, the burdensome formalization strategies make Cambodia a difficult place for firms to register their businesses in the world (World Bank and ADB, 2015).

The competitive environment of Cambodia is not conducive to promote the innovative performance of firms. According to WEF (2019), Cambodia ranks 115th of 141 countries in the domestic competition index in the GCI 2018, significantly weaker than Thailand (65th) and Vietnam (64th) (Table 3.1). Even though Cambodia has only a small number of state-run firms competing with the private ones, its formal firms face unfair competition with the informal ones. For example, formal firms perceive informal competitors as their highest constraint due to informality dominance in the economic structure (Totten et al., 2019). On the other hand, Cambodia has not yet had a competition law to manage the competitive environment.

Cambodia might recognize these constraints and has introduced the following solutions (EMC, 2017). It adopted online business registration, which can help to facilitate the business registration procedure. The targeted business registration and tax incentives policies were also initiated to promote SMEs operating their businesses in the priority sectors to formalize. Furthermore, Cambodia improved the tax system and streamlined customs and trade-related administrative procedures through launching automated clearing systems to reduce trade-related constraints. It also created a website to host the trade-related information and regulations to enhance access to them and ensure the transparency of trade-related rules. These automation practices also help to reduce the opportunities to commit corruption. Moreover, Cambodia drafted a competition law and will adopt it in the coming years.

Besides, Cambodia has offered tax holidays for 6-9 years for domestic and foreign companies located both inside and outside the SEZs when their investment projects are approved as "qualified investment projects (QIPs)." These firms are provided tax exemptions on importing capital goods and construction materials and exporting intermediate and final goods while receiving depreciation allowance when retaining their earnings for reinvestment (OECD, 2018a). However, even though the tax holidays policy is a simple form of the incentive system and is easy to implement, it is also the most costly and inefficient form of the investment incentive system (OECD, 2018a).

Cambodia appears to be successful in developing the ICT networks since it ranks 71th of 141 countries in the ICT adoption index in the GCI 2018 (Table 3.1), near to the ranking of Thailand (62th) and Vietnam (41th). To promote Cambodia to become a digital economy and move into the fourth industrial revolution, it adopted telecom and ICT development policy in 2016 to strengthen the telecom and ICT sector (Pidor, 2018). This policy can help enhance ICT security, expand the industrial sector related to telecommunication and ICT, and promote ICT usage among firms and the government. The digital signature regulation was also adopted to manage digital signatures securely and efficiently (Pidor, 2018). With these supporting mechanisms, SMEs can adopt digital technologies to produce new products or services. They can also extend their market across the country and toward South-East Asian and East Asian regions. The government tried to develop and direct the tech startup ecosystem by adopting the relevant policy and regulatory frameworks and efficiently allocating economic resources. However, some laws are missing, such as e-commerce law, cyber-security law, and privacy law.

3.2.4 Access to Finance

Financing is essential for firms to invest in equipment and machinery or expand operations or invest in innovation projects. However, Cambodian firms still have a constraint in accessing it. Cambodia ranks 88th of 141 countries in the financial system in the global competitiveness index 2018 (Table 3.1), significantly weaker than Thailand (16th) and Vietnam (60th). According to Totten et al. (2019, p. 25), even though Cambodia has a higher ranking in "getting credit" than Laos, Myanmar, or even Vietnam, its capital market is at an early development stage. It started to operate the financial market in 2012 but had only five companies to register to sell their initial public offerings (IPOs). For the credit market, almost 17% of Cambodian firms still perceive access to finance as a major constraint (EMC, 2017). While large firms are concerned about the cost of financing, small firms are worried about the complexity of the application procedure and the collateral requirement to get a loan. SMEs need to have land or real estate as collateral to get credit, and they still do not invest in productive assets when they receive the loan. In the technology sector, MSMEs are challenging to develop online portals or mobile solutions since they cannot access finance due to high-interest rates, collateral requirements, and lack of trust in "online ventures" of the financial system (UNCTAD, 2017). Even though there have been some alternatives in individual and collective solutions, they are only at the early development stage.

Cambodian SMEs still rely on conventional financing rather than risk capital options, developed only in recent years. According to CDRI (2018a), they always depend on traditional financing from commercial banks and MFIs. However, a new investment platform has been developed since 2017 to supply risk capital, especially in the tech sector. For example, during the last several years, disclosed-startup investments have increased to more than 10 with more diversified funding sources (Chan, 2018). However, the new investment platform cannot afford to fill the great financing demand of the startups and growth-oriented firms (World Bank, 2018b).

3.2.5 Human Capital

When firms can access human capital, such as qualified technicians, engineers, scientists, managers, or entrepreneurs, they can upgrade their firm capabilities to adapt to the competitive environment and technological changes. However, Cambodia has an education and training system that cannot provide adequate quantity and quality of human capital to supply the private sector to build its firm capabilities. Cambodia ranks 120th of 141 countries in the skills index in the GCI 2018 (WEF, 2019), which is significantly lower than Thailand (73th) and Vietnam (93th). Cambodian education and training system still cannot be responsive to labor market needs. Cambodia achieves a lower secondary education completion rate on average, only at 54% in 2017, while lower-middle-income countries (LMICs) achieve it at around 77% in the same year (te Valde, 2019). Cambodian firms perceive that universities are not qualified to produce human resources matching their job requirements (EMC, 2017; World Bank, 2017b). TVET is perceived as unpopular among youth and parents since its enrollment rate is too low, and it cannot address the right skills required by the labor market. Particularly, 18% of Cambodian businesses perceive an inadequately educated workforce as a major constraint, while 40% of medium-sized companies also identify it as a major constraint (EMC, 2017). In general, businesses experience difficulties in filling the vacancies with the right skills.

Cambodia has increased many activities to improve entrepreneurial education and promote the tech sector with high social impact. However, it is only emerging that Cambodia supports the SMEs that use traditional business models to build their firm capabilities. Since nearly 40% of SMEs are growing at 10% or more, upgrading SMEs' firm capabilities by supporting them in staff training and management extension services is necessary to promote economic growth (Totten et al., 2019).

Similarly, the tech talent supply cannot meet the technology sector’s demand, and the quality of the workforce does not match with the job requirements (Chan, 2018; KAS, 2018). Furthermore, the tech startup ecosystem's inclusiveness is also weak in socioeconomic, urban-rural, and gender diversity (Chan, 2018). Finally, since Cambodian universities lack a dedicated e-commerce curriculum to supply human capital for industry, innovative micro-entrepreneurs apply “learning-by-doing” to train their staff (UNCTAD, 2017). However, this practice is challenging for them.

3.2.6 Summary

Even though the business environment has been improved in general, it is not conducive to capital formation and firm capability upgrading. A favorable macroeconomic context is maintained for domestic and foreign firms to run their business and increase their investment in human capital, physical capital, and knowledge capital to upgrade their firm capabilities. Even though physical and soft infrastructures have been improved substantially, they still need to be upgraded to promote firms to participate in the international markets and move up the regional and global value chains. Business regulations still represent major constraints, inducing informal firms to stay informal. Therefore, the formal firms perceive them as major competitors. The financing represents a major constraint for the innovative firms since they can access only the traditional financial services rather than the risk capital options or innovative financial services. Therefore, it is difficult for innovative firms to get a long-term loan to implement their long-term innovation projects to capture the technological opportunities and market demand. Human capital is still limited in both quantity and quality, representing the government's significant challenges to improve and build the skills for the critical mass of both existing and future workforce.

3.3 National Innovative Performance

Cambodia has a low level of innovation activities because it has strongly focused on improving the general business environment so far. It ranks 108th of 141 countries in innovation capability in GCI 2018, significantly weaker than Thailand (50th) and Vietnam (76th) (Table 3.1). Cambodia performs research activities at a lower level if compared with its regional peers. It ranks 121th of 141 countries in the R&D indicator in GCI 2018, much lower than Thailand (56th) and Vietnam (72th) (Table 3.1). Cambodia published around 3500 research papers during 1996-2017, while Thailand achieved 157,000, Malaysia 250,000, and Singapore 270,000. Another indicator is R&D spending, which Cambodia expends only 0.12% of GDP in 2015 while Thailand, Malaysia, and Singapore commit their resources at the same year up to 0.62%, 1.3%, and 2.18% of GDP (in 2014), respectively. For the number of researchers and resident patent filings, Cambodia represented 50 per million inhabitants and 65 patents in 2015, respectively, significantly lower than Thailand (1600 researchers and 7800 patents), Malaysia (2900 researchers and 7200 patents), and Singapore (7500 researchers and 11000 patents) in 2016 (CDRI, 2018b, p.3).

Cambodia lags behind Vietnam and the Philippines in R&D spending. It has lower performance in the availability of engineers and scientists, intellectual property protection, quality of scientific research institutions, university-industry collaboration in R&D, and company spending on R&D (World Bank, 2018c, p. 20). However, Cambodian SMEs, including small growth businesses (SGB), small high growth (SHG), and medium high growth (gazelles), introduced new products or new processes and invest in R&D activities higher than firms in Myanmar, Lao PDR, and Vietnam (Totten et al., 2019, p. 21).

Furthermore, the adoptions of digital technologies in Cambodian businesses remain low since there is less than a quarter of them with a web presence in 2017, well below the world median of 46%. The number of secure servers is also lower than the regional average (Chan, 2018).

3.4 Demand Side of Cambodian NIS

Cambodian firms have low firm capabilities to learn new knowledge and technologies from external sources such as international trade, links to multinational companies (MNCs), and participation in GVCs. Cambodia needs to improve the business environment to accumulate production factors and upgrade firm capabilities to gain spillover effects from those external sources. Firms need incentives such as favorable macroeconomic context and competitive environment, proper trade regimes, and international networks, which encourage them to upgrade their capabilities. They need a conducive business and regulatory climate, financing, and the rule of law to support the accumulation of their physical, human, and knowledge capital. They also need light labor regulation, risk capital or venture capital, and solutions to knowledge externalities to accumulate knowledge capital.

Management capabilities, which are the first level of capabilities escalator, are the major complementarity factors to innovation activities (Chapter 2). Therefore, they are the central unit of analysis of NIS at the first level of capabilities escalator. Cambodia needs the business support services sector to support Cambodian firms' management capabilities at the national level while accumulating their physical and human capital through improving the business environment. When Cambodian firms' management capabilities improve at the national level, they will need to invest in R&D activities to develop their technological capabilities at the second level of the capabilities escalator. These technological capabilities can be upgraded through external sources such as international trade, multinational firms, GVCs, and government intervention in promoting in-house R&D activities. Thus, it is essential to promote the increasing presence of MNCs and the participation of Cambodian firms in international markets. To achieve this goal, Cambodia has developed economic corridors that can link economic poles in the country and connect those economic poles with the two big industrial centers, Bangkok and Ho Chi Minch. However, Cambodian firms' international integration into regional and global production networks and international markets is still at the initial development stage. The subsections will focus on how Cambodian firms integrate into international markets and regional and global value chains.

3.4.1 Integration of Domestic Firms into International Markets

While Cambodian firms can learn from international user needs and have the incentives to innovate when they compete with foreign firms in global markets, they can also access new knowledge and technologies embedded in intermediate inputs or machinery and equipment that they import. Cambodia still experiences challenges in the integration of its domestic firms into international markets. According to WEF (2019), it ranks 115th of 141 countries in the trade openness index in GCI 2018, lower than Thailand (99th) and Vietnam (91th) (Table 3.1). Cambodian SMEs contribute less than 10% of national exports (OECD, 2018b, p. 241). Vannarith et al. (2010) used a sample of 99 SMEs to study their determinants in the participation in regional production networks in South-East and East Asia regions. Even though the study was conducted ten years ago, its result is still relevant. Cambodia has not intervened substantially in firm capability upgrading programs for the last decade to strengthen the firm capabilities. The work shows that Cambodian firms have limited capacity to participate in regional production networks because they export their products into the regions in just small amounts. Cambodian firms confront some constraints such as business environment barriers, functional barriers (management and finance capacity), ability to compete (product and price barriers), and information barriers. Even though SMEs may receive some assistant services, they still need assistance in business linkages and networking, financing, overall improvement in the investment climate, and information. The business development services that Cambodian firms need include training, counseling and advice, technology development and transfer, information, business linkages, and financing. These services should be provided to develop Cambodian SMEs' capabilities. In a recent study, OECD (2018b) stated that SMEs perceived an inadequately qualified workforce, lack of finance, and non-compliance to international standards as constraints to run their businesses.

The small contribution of SMEs in export markets may derive from the lack of government support. The government has been developing only the necessary infrastructure supporting international trade, but it has not provided capacity-building services for upgrading firm capabilities. Besides, the lack of government support is also due to the fact that most Cambodian SMEs are informal and small. In 2016, only 40,000 of the total 530,000 SMEs registered in the ministry of industry and handicraft (MIH) (OECD, 2018b, p. 241). Thus, the Cambodian export structure is ‘missing the middle’ since there is an insufficient number of medium-sized exporters to participate in international markets.

Cambodia can increase export diversification and geographical export markets if it can further improve the business environment. According to World Bank doing business ranking, if a country can reduce 10% of domestic market entry costs, measured by the ease of starting a business, it can increase 1% of export product diversity (Dennis et al., 2007). However, Cambodia ranks 185th of 190 countries in the indicator of starting a business in 2019, lower than the Philippines and Lao PDR (Totten et al., 2019), suggesting that Cambodia is difficult to achieve further product export and market diversifications.

On the other hand, in the trade facilitation indicator of 2017 OECD, Cambodia had a medium score in information availability, charges, formalities-procedures, and moderate scores in formalities-documents. According to Artuso et al. (2013), if Cambodia improves the above indicators to reduce export costs to the regional average, it will increase the number of exporters two times. Shepherd et al. (2008) reported that if a country increases 10% of trade facilitation measured by World Bank doing business’s exporting cost, it can raise 3-4% of product export diversification and 5-6% of export markets. However, Cambodia ranks 115th of 190 countries in trading across borders indicators in doing business rankings in 2019, which is lower than the Philippines and Lao PDR. This ranking suggests that Cambodia still has higher trade costs than neighboring countries. It needs to pay attention to resolve them if it wants to further diversify into new high-tech industries. Cambodia needs to integrate its domestic firms with the targeted multinational firms in the Cambodian SEZs and link them with the two big industrial centers in Bangkok and Ho Chi Minh to achieve this ambition. The following subsection will discuss the linkages between domestic firms and multinational firms.

3.4.2 Linkages between Multinational Firms and Domestic Firms

Cambodia has initiated SEZs as a policy instrument since 2005 to attract FDIs in new industries and promote linkage between FDIs and the domestic economy. Cambodian SEZs appear to help create employment as well as to encourage diversification into new sectors. OECD (2018a) found that they employed about 90 000 employees, most of whom were women. They attracted new industries beyond garment and diversified the sources of FDIs such as those from Japan and the United States.

However, SEZs can create only a marginal improvement in the business environment that cannot help build SEZ firms' competitiveness. The investment climate in the zones cannot be differentiated from the broader economy. Both SEZ firms and non-SEZ firms have perceived the same top four constraints: access and reliability of electricity, lack of skilled labor, macroeconomic instability, and corruption (World Bank and ADB, 2015).

FDIs are the sources of knowledge and technologies that Cambodian firms can learn to upgrade their firm capabilities. However, Cambodian SEZs cannot deliver substantial spillover effects to the domestic economy due to the weak linkage between SEZ firms and the domestic economy (World Bank and ADB, 2015). This weak linkage is due to the domestic firms' limited absorptive capacity to gain potential benefits from MNCs (Hatsukano et al., 2014). Local industries cannot grow significantly since local SMEs still have many challenges in participating in GVCs. These challenges include limited access to finance, shortage of skilled workers, lack of compliance with essential standards. They impede the local SMEs from having good relationships with foreign firms, so SMEs cannot learn higher skills from foreign firms to upgrade their capabilities.

Remarkably, Cambodia leaves the private sector to invest in SEZs, its main feature different from other countries. Even though Cambodian SEZs still cannot leverage the linkage between SEZ firms and the domestic economy, they don't impede development by de-investing resources from improving the overall investment climate. These SEZs are run and managed by private investors on the one hand. On the other hand, investment incentives are applied to both SEZ firms and non-SEZ firms (OECD, 2018a).

SEZs can help to promote cluster development by attracting Cambodian SMEs to locate in them through creating the appropriate mechanisms to encourage SMEs to interact with MNCs to learn new knowledge and technologies from the latter. Cambodia has 22 special economic zones (SEZs) operating in different regions, such as Phnom Penh, Sihanoukville, Bavet, and Poipet (Warr et al., 2015). The state of cluster development has been improved, which is not so far from neighboring countries. Cambodia ranks 64th of 141 countries in the state of cluster development in GCI 2018, not so lower ranking than Thailand (47th) and Vietnam (44th) (Table 3.1). UNDP (2014) studied the linkage between domestic firms and MNCs in the Cambodian economy and found that the backward linkage was weak in manufacturing sectors due to the weak performance of local supporting industries. However, this linkage appeared more assertive in the services sector. The horizontal linkage was significantly negative even in the services sector.

On the other hand, the forward linkage was significantly negative in the manufacturing sector. The forward linkage significantly impacts developing domestic firms' absorptive capacity, even though the technology gap between them and foreign firms is still significant. However, domestic firms with higher absorptive capacity can benefit from multinational firms through horizontal and backward linkages.

Cambodian firms cannot benefit from the agglomeration economy since the extent of productivity spillover effects is lower than that of the adverse competition effects. Sokthy et al. (2014), using economic census survey 2011, found that firms locating in the clustering of economic activities gain productivity spillover effects less than they lose from negative competition effects; thus, they experience adverse agglomeration effects in general. Informal and manufacturing firms experience productivity spillovers' observed benefits, even though they still receive adverse competition effects. On the other hand, formal and manufacturing firms face more pronounced competition effects than informal and services sector firms. The result that the competition effect outweighs the productivity spillover effect is similar to that of the study of Siba et al. (2012).

3.4.3 Cambodian Firm Capabilities

To promote structural transformation, Cambodia needs to promote FDIs in higher value-added and new industries while upgrading domestic firms' capabilities to absorb new knowledge and technologies from MNCs. However, entrepreneurship is limited in Cambodia, even in the dominant garment industry. Cambodia ranks 76th of 141 countries in entrepreneurial culture in GCI 2018, nearly on par with Vietnam (68th) but significantly weaker than Thailand (33th) (Table 3.1). Based on the economic census 2011, UNDP (2013) showed that firms with employees between 100 and 499 have Cambodian ownership, only 66.2% out of a total of 545 firms. While firms with employees between 500 and 999 represent Cambodian ownership, only 46.3% out of a total of 123 firms, firms with more than 1000 represent Cambodian ownership, only 35.3% out of total 119 firms. In particular, garment and footwear industries are owned by Cambodian entrepreneurs, even a smaller number of firms.

There are two reasons to explain the causes of the weak domestic entrepreneurship. First, Cambodian firms have lower organizational and technological capabilities; thus, they represent a small share of all export-oriented large firms. Therefore, they require less demand in investment funds and skilled laborers due to their low competitiveness in the global market. Second, this weak domestic entrepreneurship may also derive from the fact that the return from natural resource rents is higher than productive industries' return. To resolve domestic entrepreneurs' low participation rate in export markets, the government needs to address the rent capture problem simultaneously with fixing the low level of organizational and technological capabilities common among Cambodian firms (UNDP, 2013).

Managerial and organizational capabilities are essential for firms to identify technological opportunities, develop long-term innovation projects to exploit them, and cultivate human resources to execute the innovation projects successfully. They are the central unit of analysis of the NIS at an early stage of the capabilities escalator. However, Cambodia has limited management and production capabilities, and management extension services for upgrading them are still underdeveloped. According to OECD (2018a), Cambodian firms have limited absorptive capacity because the business development services sector is still emerging, and government support in upgrading the absorptive capacity is still low at the national level (MIH, 2015). Cambodia has started only in recent years to promote and strengthen micro and small firms that use traditional business models (Totten et al., 2019). On the other hand, even though Cambodia has developed policy documents focusing on developing productivity and innovation, it cannot effectively implement them (OECD, 2018b; MIH, 2015).

In order to upgrade the firm capabilities at the national level and move from the first to the second level of the capabilities escalator, Cambodia needs to identify the growth potential firms and mobilize the critical mass of them by supporting them through the firm life cycle. According to Totten et al. (2019), two types of firms can become potential candidates for public support. They include small high growth businesses (SHBs) and medium growth businesses (Gazelles) that are more likely to expand their operations and export to international markets. However, without government support to upgrade their firm capabilities, Cambodia’s export structure will continue to be characterized as ‘missing the middle.’ Upgrading these firms' capabilities can resolve the missing middle export structure and promote national competitiveness and catching up. SHBs and Gazelles need government support in international networking and trade facilitation to access foreign suppliers and clients (Totten et al., 2019).

In this sense, when these firms want to expand their operations, they will counter-face significant challenges such as acquiring access to finance, formulating growth strategy, scaling up the operations, and accessing the growth markets. Furthermore, when they grow their businesses; subsequently, they will attract and retain high-skilled employees in the long-term innovation projects and delegate the authority. According to Totten et al. (2019), to support the firm capability to upgrade for the whole firm life cycle, Cambodia should create an Entrepreneurship Promotion Center (EPC) like SPRING in Singapore. EPC can play the role of an institute of higher learning for mentorship and idea generation. It can also function as incubators and accelerators to support the early stage of funding and idea commercialization and as business angel investors to support equity investment and marketing before developing them to become global enterprises.

On the other hand, Cambodia's tech startup ecosystem is still emerging in recent years to support entrepreneurship and tech startups. Most startups are in the pre-seed and early stages, and their firm capabilities are still limited; therefore, they are not widely ready for investments (Chan, 2018). The ecosystem still faces some challenges, including limited access to tech innovation education, business support services, limited market analysis capacity, and social networking fragmentations. According to World Bank (2018b), several main reasons are impeding Cambodia's digital economy. First, tech startups are experiencing limited uptake of digital financial services. Second, they lack human resources with IT skills. Third, there is an incomplete legal framework to support the digital adoption of businesses. However, tech startups are becoming more popular among young graduates and professionals since there is an increasing number of pitching competitions, hackathons, and startup support programs. The rising popularity of tech startups also derives from the well-recognized “hero” tech entrepreneurs in the world and the increasing Cambodian startup role models (Kem et al., 2019).

3.4.4 Summary

Cambodia represents the increasing demand side of the NIS. When macroeconomic performance and framework conditions have been significantly improved to accumulate the physical and human capital to increase the firms’ operations, Cambodian firms need to upgrade their management and production capabilities to integrate themselves into international markets, RVCs, and GVCs and to become global firms. The government can mobilize the critical mass of medium-sized exporters, SME suppliers, innovative domestic firms by supporting them through their firm life cycle. When their management capabilities have been upgraded, they can capture the technological opportunities, market demand, and institutional settings, so they tend to invest in innovation projects to learn new knowledge and technologies from multinational firms or universities and public R&D institutes. Then, the demand for the R&D activities conducted by universities and R&D institutes will increase from SMEs’ R&D cooperation demand to support them in upgrading their technological capabilities. Even though Cambodia initially has a low level of innovation activities, it can increase the innovation activities to a higher level by adopting the supply side of NIS and implementing them according to the three stages of the capabilities escalator.

3.5 Supply Side of Cambodian NIS

Cambodia still has limited management capabilities and low-skilled workers among its SMEs. The education and training system needs to supply skilled human resources to firms while firm capability upgrading programs are needed to improve SMEs' management capabilities. This improved management capabilities of Cambodian firms will increase research and innovation demand at the national level. While this demand increases, it is necessary for Cambodia to invest in frontier research in universities and public research institutes to support firms' real needs in the priority sectors.

To understand the extent of the demand for which the supply side of NIS needs to fulfill in the Cambodian economy, Yun et al. (2015) studied the effects of the open innovation policies on Cambodia's national competitiveness. They did an extensive literature review to build a NIS causal loop diagram and system dynamics (SD) model to analyze the impact of open innovation policies on NIS. The result has been applied to Cambodia. Open innovation policies are characterized by the simultaneous creation, distribution, and consumption of knowledge and technologies. The simulation result shows that even though moderate open innovation policies slightly impact Cambodian NIS to promote national competitiveness in the short term, the impact does not last for a long time. However, a higher level of open innovation policies does help promote a persistent effect on national competitiveness in the long-term by upgrading Cambodian NIS for production, distribution, and consumption of new knowledge and technologies.

This study suggests Cambodia develop a national science and technology master plan to promote production, diffusion, and use of new knowledge and technologies to a large extent to have a significant impact on sustainable economic development. However, Cambodian NIS is an emergent innovation system. Management capabilities and human capital are the central units of analysis, so balancing this focus with the science and technology system is necessary. While developing the science and technology system to support domestic firms, their management capabilities also need to be upgraded to learn new knowledge and technologies from the interaction with multinational firms or universities and public R&D institutes. On the other hand, to develop a good science and technology system, Cambodia needs a critical mass of technicians, engineers, scientists, and researchers to work for the universities, technology extension institutes, R&D institutes, and the private sector. Therefore, it needs to prepare the national human resource planning and adopt some budget to invest in these human resources while adopting the incentives and reward system to mobilize the diaspora and existing qualified researchers, engineers, and scientists to work for those organizations.

This section is organized as follows. Subsection 3.4.1 focuses on the national education and training system, while subsection 3.4.2 on public agencies for upgrading firm capabilities. In subsection 3.4.3, universities and R&D institutes' roles will be reviewed, followed by the role of university-industry linkage in subsection 3.4.4. Subsection 3.4.5 will summarize the main points.

3.5.1 National Education and Training System

Cambodia lacks human capital to promote new industries and move up the GVCs while pursuing industry 4.0. It still has challenges in forthcoming young and existing labor forces (World Bank, 2018a). The human capital shortage may derive from the higher education system's fragmented governance (Un et al., 2018, p. 2). Sixteen ministries control Cambodian HEIs. Among all HEIs, 73 HEIs are supervised by MoEYS, 25 HEIs by MoLVT, and other ministries control the remaining. MoEYS manages the academic stream through the General Directorate of Higher Education with the two departments. The Department of Higher Education oversees the associate and undergraduate students' education, and the Department of Scientific Research supervises the education and research of the graduate and post-graduate students. MoLVT manages the technical and vocational training stream under the direct control of the General Directorate of Vocational Education and Training. However, there is no strategic coordination between these ministries.

Even though Cambodia has the Accreditation Committee of Cambodia (ACC) to control the quality standard of higher education, its scale and scope of the operation is still small, so it doesn’t have a significant impact on strengthening the quality of higher education yet. Cambodia spends the education budget on the higher education sector less than its comparator countries in the region in terms of the funding system. On average, it spent 2% of the education budget on the higher education sector in the 1990s, 4% in 2013, and 9% in 2016 (Un et al., 2018, p. 5). Generally, Cambodia invests in the higher education sector at only 0.1% of GDP, which is lower than the world average of 1% of GDP.

The higher education sector's institutional management needs adequate teaching staff and their involvement to expand the operation and meet society's quality and relevancy and economic development. However, the teaching staff increase is not matched with the increase in students' number, resulting in larger class size, more significant student-staff ratio, and student-laboratory/ library ratios. Besides, there are more shifts at many HEIs among both students and teaching staff. Based on these problems, the quality of education is commonly compromised. Simultaneously, rote-based and teacher-centered methods are generally applied in teaching, limiting teachers' opportunities to improve their skills and exposure beyond their institutions. The curriculum is always copied from other better institutions without adapting it to the local context. Book writing is infrequent and is not adequately incentivized, so most lecturers adopt a foreign language textbook, which is not relevant to developing the skills of the Cambodian context.

With such critical challenges, the national education and training system needs to be upgraded to resolve them. To prepare the young labor force for promoting structural transformation, the government needs to develop the national S&T education and training system to build S&T talent in priority sectors. According to CDRI (2018a), Cambodia needs to promote STEM education while focusing on upgrading STEM teachers' capacity to drive it successfully. STEM education needs to be accompanied by multi-disciplinary skills such as economics, commerce, and finance to enhance career paths. In this sense, TVET plays dual roles in providing relevant skills matching with labor market needs and developing the student's ability to adapt to new technologies (CDR, 2018a). Therefore, it needs to strengthen basic numeracy and literacy skills while developing soft skills like problem-solving, communication, and adaptability, encouraging applying different skills in different real-life situations. Besides, it should promote life-long learning rather than focus only on the preparation of specific skills for the labor market. For the higher education sector, the OECD (2018a) suggested strengthening the higher education system to supply qualified technicians, engineers, scientists, and entrepreneurs who can help upgrade the manufacturing SMEs' production and technological capabilities in higher value-added products and services.

Remarkably, Cambodia has a dominant share of youth among its population, so developing entrepreneurial knowledge and youth skills will harness its economic development strength. The entrepreneurship curriculum needs to be incorporated into every education level to build leadership and entrepreneurship values. The training-of-trainers program also needs to be developed to supply adequate entrepreneurship educators to support the agenda of entrepreneurial education and training as a whole (World Bank, 2018b).

To cope with tech startups' human capital challenges, the government needs to introduce some similar solutions. Chan (2018) proposed universities and training institutes to work closely with industry and startups to develop entrepreneurship and innovation programs providing skills matching with labor market requirements. They also need to strengthen the capacity of teachers and training centers to effectively implement the new curriculum to upgrade the quality standard of education. With collaboration with regional universities or the development of international programs, universities and training providers can adopt innovative solutions to provide rapid skills training such as distance-learning programs. Furthermore, digital literacy needs to be enhanced since childhood. The government needs to promote student diversity in socio-economic, urban-rural, gender, and language to develop the inclusive tech startup ecosystem. Besides, the ICT federation can be empowered to play an essential role in informing the job requirement of ICT and e-commerce skills to universities and training institutes to develop their curriculum matching with the MSMEs' needs (UNCTAD, 2017). Finally, Cambodia needs to build IT skills by adopting and implementing the digital skills readiness strategy (World Bank, 2018b).

In addition, the government needs to promote upskilling and reskilling programs to encourage current employees to continue their studies at the next level or work in different fields while developing joint qualification routes with universities to promote them to earn their next degree in education (CDRI, 2018a). World Bank (2018a) proposed a levy grant system developed and applied successfully in South Korea, Malaysia, and Singapore to be used in Cambodia to build its skills. In this system, firms are required to pay the training levy first and get reimbursed on the condition that the training expenses are incurred. In this manner, corruption practice has been minimized. The levy grant system can help increase the number of firms receiving benefits from this grant while improving the current workforce's number to receive in-house or on-the-job training and training services from external training programs. Finally, it is a demand-driven system since firms are the ones who organized and purchased training services by themselves. Both public and private training providers need to become more efficient since they need to compete in the training market to get selected by the enterprises.

3.5.2 Supporting Agencies for Upgrading Firm Capabilities

Cambodia has a low level of management and production capabilities that is a challenge it cannot move up to the next level of the capabilities escalator. Firms need internationally-recognized product standards to comply with, advanced business consulting services to help improve their management and production capabilities, and financing to accumulate human, physical, and knowledge capital. Provided these supports to upgrade their management and production capabilities, Cambodian firms can become successful exporters, innovative local suppliers, tech SMEs or global firms. However, these three needs still represent challenges for them. The following subsections will review the basic national qualification infrastructure (NQI), business development services, and financing.

3.5.2.1 Basic National Qualification Infrastructure (NQI)

Institute of Standards Cambodia (ISC) is responsible for adopting national standards and diffusing them to national firms to comply with them. The National Standards Council assigns ISC to adjust and adopt ASEAN standards to become Cambodian standards. However, national qualification infrastructure is still at the early stage of development. Most Cambodian businesses still need to use laboratories in Thailand or Vietnam to test product standards for exporting to international markets. Even though the Industrial Laboratory Centre of Cambodia's (ILCC) capacity has slightly been improved, SMEs perceive its limitations in product coverage and low test robustness. According to the ISC mid-term master plan 2016-2020, development partners have supported substantial resources to developing national laboratories, especially in sanitary and phytosanitary (SPS) and technical barriers to trade (TBT). However, only two laboratories received international accreditation with only a narrow set of parameters. This limited support for SMEs to test their product standards to adapt to the internationally-recognized national and international standards has made their products less competitive in the domestic and international markets (OECD, 2018b).

3.5.2.2 Business Development Services

Upgrading management capabilities is the strategic priority for raising Cambodian NIS to the next level of capabilities escalator. Cambodian firms' management capabilities are still low, so they need business development services (BDS) and financing to support them. In this regard, Cambodia has developed an SME development policy, which has three main objectives: 1) to create an enabling business environment 2) to strengthen SME capacity 3) to develop and provide business support services for SMEs. However, Cambodia still reveals the challenges in implementing it effectively since it lacks coordination among various development policies and agencies. According to CDRI (2018a), this SME development policy should be coordinated with Industrial Development Policy 2015-2025 and should be systematically implemented to obtain extensive SME development impacts.

Cambodia plans to create an Entrepreneurship Promotion Center that can help build firm capabilities and provide financial support through different firm life cycle stages. Cambodia has also tried to upgrade the National Productivity Center of Cambodia's (NPCC) capacity to support competence building and firm capability upgrading (MIH, 2015). According to the Japanese expert team, NPCC needs to develop its ability to become the best business development services provider (BDSP) to promote the private BDSP sector by expanding its capacity to meet the international consulting services standard. By this commitment, Cambodia can increase the consulting services' supply side to fulfill the demand of its large number of existing potential SMEs and startups to build their competitiveness in domestic and international markets. Cambodia Trade Integration Strategy 2014-18 also suggested providing information and matchmaking services to local suppliers while creating supplier development programs to support them, especially SMEs in SEZs, to integrate them with multinational firms. When the critical mass of highly-upgraded capability firms are obtained, the demand for frontier research and innovation supplied by universities and public research institutes also increases.

OECD (2018b) proposed the government strengthen the implementation of the established SME development policy. It should develop BDS and innovation promotion infrastructures to meet the demand for SMEs' BDS and increase demand for the innovation-development activities conducted by universities and public research institutes to support the more advanced SMEs. The BDS and innovation promotion infrastructures include business support centers, incubators, accelerators, and one-stop-shops.

On the other hand, the tech startup ecosystem is still emerging. Each stakeholder's capability needs to be strengthened, and linkage needs to be promoted to develop innovation and digital transformation. To upgrade their products and services, startups need to collaborate with other startups while accessing experienced mentors through structured regional programs and industry linkages to learn new knowledge and technologies. They also need to engage the overall market rather than focus on only the capital city or only in the specific sectors. This way, they can learn and solve widespread market needs in the whole economy (Chan, 2018).

Besides, investors and corporates need to develop themselves as strategic mentoring partners to help build firm capabilities along the investment process by providing BDS and technical skills beyond supplying financial resources. Investors can enhance investor sophistication in Cambodia by participating in local and regional investors' networking events, engaging them with experienced venture capital and tech investment professionals. For corporates, they can help upgrade ecosystems by providing direct mentorship, feedback, and business insights for startup teams. Chan (2018) proposed Cambodia develop adequate innovation facilities, promote equal opportunities to participate in training programs, fulfill the mentoring gap, build entrepreneurs' commitments, and leverage potential regional opportunities for local investments to upgrade the tech innovation ecosystem.

3.5.2.3 SME Financing and Venture Capital

When SMEs can access financing, they can expand their operations by increasing their human, physical, and knowledge capital to capture the identified technological opportunities and domestic and international market demand. However, Cambodian SMEs represent challenges in accessing it since they can afford only the traditional financial services but not the risk capital options and other innovative financial services. To cope with these problems, Cambodia tries to improve credit information, secure transactions, and service diversification. According to Financial Sector Development Strategy 2016-2020, Cambodia needs to extend Credit Bureau Cambodia coverage (CBC) to include firm data (Totten et al., 2019). It also considers adopting credit guarantee schemes to promote MSMEs to access to finance. In the SME development policy, Cambodia also plans to create an SME-oriented bank to provide innovative financial services and risk capital options in addition to traditional financial services offered by the current conventional banking system.

According to a recent study by World Bank (2020), Cambodia has introduced Guarantee Scheme Corporation of Cambodia (GSCC) to adopt credit guarantee schemes to promote commercial banks and microfinance institutions to provide soft loans to support SMEs in the pandemic Covid-19 crisis period. The SME bank began its operation in early 2020 to support SMEs with its SME co-financing services. These services are loans arranged by matching between SME bank and commercial banks or microfinance institutions with subsidized interest rates, designed to prevent SMEs from closing their operations during the pandemic Covid-19 and recover quickly during post-pandemic Covid-19. According to UNCTAD (2017), Cambodia needs to promote banks to create innovative financial products specific to MSMEs investing in e-commerce. With the rising fintech, Cambodia needs to adopt other financing options such as cryptocurrency using blockchain technology, crowdfunding sources of investments, peer-to-peer learning, angel investment, and venture capital (CDRI, 2018a). Finally, Cambodia should also enhance business associations to support MSME members to have higher credibility and bankability (UNCTAD, 2017).

Cambodia needs to promote corporates and domestic investors to invest in startups and tech SMEs while providing complementary support to develop them. According to Chan (2018), corporates are more interested in investing in tech startups to promote innovation and digital transformation. The technology sector is desirable to local investors, leading to increased Cambodian-owned venture capital and angel investors. However, individual and institutional investors don't strategically support complementary factors to build firm capabilities of startups other than an investment fund. They are likely to target the acquisition with large equity stakes early, removing the founders' incentives to continue their innovation and digital transformation.

3.5.3 Universities and Public Research Institutes

Even though Cambodia still has a small number of innovative firms that need frontier research and innovation, it still needs to upgrade its R&D capability at this time. The R&D system needs time to develop to support the innovative performance of firms efficiently. However, Cambodia still has limited capacity in this field. It ranks 117th of 141 countries in the quality of research institutions in the global competitiveness index 2018, significantly weaker than Thailand (43th) and Vietnam (58th) (Table 3.1).

According to Dy (2013), several reasons may explain the limited R&D capability. First, Cambodia lacks financial commitments to developing research and innovation in universities and public research institutes. It remains relying on development partners such as World Bank, UNDP, and ADB to fund research projects. Second, research and innovation management is not sufficient because the government has not politically committed to expanding research and innovation opportunities in various areas, especially in politically sensitive areas. Third, the incentives and reward system has not been adopted for encouraging researchers and higher qualified persons in higher education institutions (HEIs) and public research institutes to engage in research activities. Fourth, HEIs are operating as a commercial enterprise to provide education services, ignoring the field of research. They may be producing human resources lacking the essential research skills for future national development or the labor market. Finally, research cooperation between public and private sectors has rarely occurred because research culture has been poorly developed in Cambodia.

According to Kitamura et al. (2016), Cambodia has no well-developed system to support academic research in the HEIs. Faculty members don't have enough time and lack funding, facilities, and educational equipment for doing research. Also, HEIs have limited human resources for conducting research activities. According to DRF (2010), most Cambodian universities function as a teaching institution, even though several public universities show increasing research activities. Research is not the core mission of most universities; thus, they don't have a clear research policy to support their faculty research. Finally, the research is commonly characterized as student research, which is always compromised when the lecturers are not active in it.

To develop research and innovation at the institutional level, the government needs to establish a new policy focusing on the management of autonomous public-funded research universities, in which lecturers must be qualified in both teaching and research at the national standard level. On the other hand, to develop research and innovation at the policy level, Cambodia needs to consider several measures. Cambodia should formulate a national roadmap to coordinate various ministries and institutions to promote and enhance the science and technology system in which research is the key to this development. It also needs to try to strengthen the research capacity of the highly educated Cambodians by encouraging them to participate in research-based collaboration with colleagues in other countries through networks, such as the South-East Asian Ministers of Education Organization (SEAMEO) and ASEAN University Network (AUN) (Dy, 2013).

According to CDRI (2018b), Cambodia needs to build R&D infrastructure and networks by initiating the government-led program in R&D activities and networks, introducing foreign technologies, and mobilizing local talents to promote the development of technology and innovation. It also needs to encourage technological adoptions among Cambodian firms by organizing technology and innovation shows, technology and innovation databases, technological incubation centers, and technology and innovation parks while developing a technology adoption incentives system.

3.5.4 University-Industry Linkage

Cambodia has a lower university-industry linkage level, even though this linkage can promote education quality and help develop, diffuse, and use the innovations. Cambodia ranks 82th of 141 countries in multi-stakeholder collaboration in the global competitiveness index 2018, nearly on par with Vietnam (80th) but significantly weaker than Thailand (40th) (Table 3.1). Using a sample of 46 participants from relevant institutions, Sam et al. (2017) found that even though stakeholder categories such as government, development partners, HEIs, and industries are involved to a certain degree in developing the higher education sector, their collaboration is still weak.

This empirical evidence shows that government and donors play a critical role in policy adopting and financial interventions to support the higher education sector, even though the mechanism is still absent to promote collaboration. Industries and NGOs play a limited role as employers, internship providers, and trainers due to their lack of capacity and resources to link with HEIs. HEIs themselves also lack functional ability and resources to develop qualified human resources meeting the requirements of industries. Furthermore, they have no strategic plans to promote collaboration with industries and other stakeholders, which is essential for developing and diffusing innovation in the knowledge-based economy. According to Sam et al. (2016), Cambodia faces some challenges in orientating the higher education sector into the regional or global trend, which tends to develop the universities to become entrepreneurial ones. The weak linkage between universities and industries makes the Cambodian universities lose the opportunities to diversify their income sources and promote higher education and economic development. When other ASEAN members such as Malaysia, Singapore, and Thailand try to develop their universities to become entrepreneurial universities, Cambodia adopts the commercial-oriented ones.

According to CDRI (2018a), Cambodia needs to promote joint S&T applied research activities and technical collaborations and partnerships between schools and industries to upgrade learners' and STEM graduates' skills to match with job requirements in industry 4.0. It should also use the university-industry linkage approach to investigate future job requirements and labor market demand in new sectors, sourcing inputs from businesses through their collaboration with education and training institutes and government agencies. Those businesses can pool their resources to develop new skill sets in the future priority sectors by fostering cross-industry collaboration and public-private partnership.

Public-private partnerships in the university-industry interaction need to be developed to produce new technology and innovation and upgrade education and training quality to match the industry's needs. The government plays an essential role in encouraging the university-industry linkage by providing an incentives system in various forms to direct collaborations in the priority sectors. Enterprises introduce technical requirements to researchers in universities and use the university-industry linkage to perform joint R&D activities to find technical solutions. Their needs are extensive if they try to develop technological systems to produce new products or processes. On the other hand, universities play a role as a university-industry linkage manager controlling the financial flow of collaboration projects to provide appropriate incentives and a sound R&D environment for researchers to perform R&D activities. Finally, researchers play a role in conducting R&D activities and mentoring other researchers in their early career development.

3.5.5 Summary

The Cambodian NIS's supply side is emerging since some public organizations have low capabilities, while some are new or non-existent. Thus, the Cambodian NIS is not functioning well. Even though the national education and training system has improved during the last two decades, it still has critical challenges in building skills for the future workforce and upgrading the existing ones. While the critical mass of medium-sized exporters, innovative local suppliers, and tech firms needed to be mobilized to integrate them into international markets, RVCs, and GVCs, the firm capability upgrading system is still limited in scale and scope to support those firms. As a result, the export structure is missing the middle. The linkage between local suppliers and multinational firms is weak. Only a small number of startups and innovative domestic firms can operate their businesses successfully in domestic and international markets. The quality of public research institutions is still low, and their collaboration with industries is still limited. Cambodia needs to plan the human resources to upgrade these public and private organizations by providing scholarships to each HEI's best students to continue their master's and a Ph.D. degree in the advanced countries. It also needs to adopt the incentives and reward system to mobilize the local talents and qualified diaspora to join the public institutions and private firms to upgrade their organizational and technological capabilities.

3.6 Conclusion

Cambodian NIS is characterized as an emergent innovation system; however, it can be upgraded to become a well-functioning NIS. Cambodia ranks 106th of 141 countries in the overall score in the global competitiveness index 2018, significantly weaker than Thailand (40th) and Vietnam (67th) (Table 3.1). Cambodia has experienced growth in trade and FDIs and macroeconomic stability. However, its infrastructure is still poor and raises the cost of doing business and exporting so that most SMEs cannot participate in international markets. On the other hand, ICT infrastructure has been improved significantly to promote the digital transformation of industrial activities. Even though business environment and regulations have improved steadily, they are still burdensome and discourage many Cambodian firms from getting out of informality. As a result, informal competitors become the most significant threat to the growth of formal firms. Even though Cambodian capital market is still weak, its credit market is now more developed. However, it depends mainly on traditional financial services rather than risk capital and other innovative financial services, supporting long-term innovation projects and the adoption of digital technology.

Cambodia's workforce has a lower education level than similar countries. The current education and training system still seems unable to prepare students for the new needs of the labor market in priority sectors, in particular for the digital economy. Cambodia has limited management extension services to upgrade the capabilities of existing SMEs and startups since business development services sector is still small in scope and scale. As a result, management capabilities are limited and there is little demand for R&D investment among Cambodian firms. Additional problems derive from the lack of skilled workers and financing such as risk capital and other innovative financial services. Therefore, Cambodian firms cannot absorb new knowledge and technologies from the increasing presence of multinational firms. Furthermore, Cambodia has a limited number of exporters due to burdensome business regulations, high exporting costs, poor quality infrastructure, in addition to limited management capabilities and a low level of R&D investment. Consequently, the links between multinational firms located in SEZs and domestic firms are weak due to the latter's low absorptive capacity. On the other hand, the university-industry linkage is low in Cambodia because firms and educational institutions operate with only basic management capabilities. They do not intend to interact with each other to develop new knowledge and technologies or promote higher education and training quality.

Policymakers have not yet treated innovation policy with a pragmatic policy agenda. There is still a lack of coordination among various innovation agencies, which prevents building science-based competencies and firm capabilities and promoting dynamic spillover effects from MNCs to local firms. Cambodia's integration into dynamic emerging regions is still limited, which further delays its technological level compared to the rapidly expanding technological frontier (OECD, 2013).

In comparison, Thailand and Vietnam can be characterized as maturing NIS. They have a better conducive business environment since indicators such as macroeconomic stability, openness of trade, ICT adoption, domestic competition, financial system, and skills reveal higher rankings than Cambodia. Thus, their NIS tends to focus on developing innovation capabilities more than Cambodia. As shown in Table 3.1, their ranking is higher in innovation capability, R&D, state of cluster development, quality of research institutions, and multi-stakeholder collaborations. Between Thailand and Vietnam, Thailand's NIS is more mature than Vietnam.

However, according to OECD (2013), Cambodia can successfully upgrade its NIS by improving its educational system and business environment. Given the large proportion of the young population, the science and engineering education system needs to be strengthened to train skilled human resources and help improve firms' capabilities. Entrepreneurship and innovation programs need to be developed in both universities and schools to upgrade young entrepreneurs' competencies and facilitate the digital transformation of the economy. On the other hand, Cambodia could adopt a 'levy grant system' to organize training services for the current workforce.

With the increasing presence of multinational firms as global knowledge and technologies sources, Cambodia needs to create an Entrepreneurship Promotion Center (EPC) and strengthen the

National Productivity Center of Cambodia (NPCC) to upgrade firm capabilities. This could help Cambodian firms to reach the critical mass needed to produce parts and components for multinational firms and international markets. The establishment of an SME-oriented bank is also necessary as it could provide innovative banking services, risk capital options, and credit guarantee schemes that could help SMEs to access the long-term loans needed to invest in innovation projects.

Since most multinational firms are located in SEZs, creating favorable conditions for the transfer of SMEs to SEZs could encourage knowledge and technology spillovers to improve management and technological capabilities. It is essential to adopt and implement innovation policy instruments that allow SMEs to move into the SEZs and encourage them to cooperate with other firms. SMEs should receive matchmaking information and services and should be supported by supplier development programs to enhance their capabilities and learn from multinational firms.

The Cambodian private sector represents the demand side of NIS. As firms grow, so does the demand for R&D activities provided by universities and research institutes. In this regard, Cambodia must promote the value of S&T among government agencies, universities, researchers, industries, and the public (CDRI, 2018a). Cambodia must also understand its human resource needs and find foreign university partners in developed countries where it can send the best students to earn master and Ph.D. degrees by providing them with the scholarship. Incentives and reward systems need to be adapted to nurture top talents and attract the diaspora to work in the country. When the critical mass of talents is mobilized, it is easy to develop the science and technology system that can support the firms' capacity building and technological development. While developing S&T infrastructures with a well-coordinated framework and regulation, Cambodia should also equip them with adequate resources to carry out R&D activities by diversifying funding sources between foreign, domestic private, and public finance. In addition, the government must develop the mechanism to facilitate patent applications in every registration office in Cambodia, promoting the digital transformation of manufacturing SMEs by providing a good incentive system.

Chapter 4: Innovation and Productivity at the Firm Level in Cambodia: Can Cambodia Catch Up with the Technological Frontier Economies?

4.1 Introduction

Cambodia has experienced an economic growth rate of around 7% for the last two decades, even though it started from the GDP's low base. To maintain the same growth rate, it needs to develop the selective innovation policies necessary to resolve the systematic problems. These problems can be discovered and understood by applying the national innovation system concept to analyze the Cambodian innovation performance at the firm level.

However, the NIS concept is likely to be context specificity. While developed countries tend to develop their R&D capabilities to support their private sectors to produce frontier technologies, R&D investment is not relevant in developing countries (Cirera et al., 2017). This contrast may derive from the fact that developed countries have various adequate policies to support their general business environment, promoting them to invest in the complementary factors to innovation. On the contrary, developing countries lack these policies to support the business environment, so they tend to underinvest in R&D activities. Cambodia is not an exception.

Cambodia has developed the Rectangular Strategy (RS), which covers the economic, social, political, financial, and institutional issues to promote sustainable economic development (RGC, 2018). It aims to achieve four strategic goals, including growth, employment, equity, and efficiency. To achieve these goals, RS has adopted four main priority areas: human resource development, economic diversification, development of the private sector and quality jobs, and promoting inclusive and sustainable development. On the other hand, governance reform is necessary to improve the general business environment for promoting the private sector to do their business successfully while strengthening the government's ability to efficiently implement the various development policies. These different development policies include Industrial Development Policy 2015-2025, Diagnostic Trade Integration Strategy and Trade Swap Roadmap 2014-2018, and National Science and Technology Master Plan 2014-2020.

Industrial Development Policy 2015-2025 was developed to draw the road map of various development policies that needed to be implemented by different ministries and administrative units (RGC, 2015). It has the vision to transform and modernize its labor-intensive industry to become a skill-based industry by 2025. Cambodia Trade Integration Strategy 2014-2018 aims to develop the top ten priority export sectors: garment, footwear, light manufacturing, processed food, fisheries, milled rice, cassava, natural rubber, tourism, and silk (RGC, 2014). To achieve this goal, the government tried to develop physical and soft infrastructures to reduce import and export costs to promote foreign and domestic direct investments to participate in the supply industries in those priority export sectors to build their competitiveness in the international markets. It needs to create supplier development programs and support the information and matchmaking services to upgrade its supply industries. In this manner, these supporting initiatives can help strengthen domestic suppliers' firm capabilities to produce parts and components matched to exporting firms' requirements. To enhance firm capabilities, firms need skilled workers, which are limited in terms of quantity and quality. The skills gap and shortage should also be resolved by strengthening the technical and vocational education training system to develop the curriculum to create the current and new labor force's skills to match the labor market need in the priority export sectors. Rice policy 2010 was implemented successfully to provide financing and other supports to promote paddy rice production and milled rice export. Such a sectoral policy is recommended to replicate into other priority export sectors. Besides, National Science and Technology Master Plan 2014-2020 was prepared to design policy, budget, organization, R&D, and cooperation to secure the S&T foundation to develop the agriculture, primary industry, and ICT sectors (RGC, 2013).

However, they haven't shown any conceptual framework that can explain the systematic problems rather than the individual parts (OECD, 2013). As a solution, the NIS concept can be used as a conceptual framework to analyze the economic data in order to understand real economic situations, which can be used to adopt the evidence-based innovation policy.

The purpose of Chapter 4 is to analyze the Cambodian national innovation system by adopting the concept of the "expanded national innovation system" proposed in Chapter 2 and extend it to the Cambodian economic context. To understand it, we suggest the following research questions that should be appropriately answered.

Research Questions

1. What are the determinants of innovation input investments?
2. What is the relationship between innovation input investments and innovation outcomes?
3. What is the relationship between innovation outcomes and labor productivity?

To answer the above research questions, we adopt the CDM model proposed by Crépon, Duguet, and Mairesse (1998) and extend it to adapt to the Cambodian economic context. Furthermore, we use the generalized structural equation model (GSEM) applying the full information maximum likelihood (FIML) estimation method rather than using the asymptotic least square (ALS) estimation method applied in the original CDM model. Sensitivity analysis will be done to understand the model under different assumptions. A robustness check will be done to compare the present econometric result with the sequential instrumental variable (IV) estimation method used by Griffith et al. (2006) and the structural equation model (SEM) used by Cirera et al. (2016a).

Cambodian NIS is characterized as an emergent innovation system. The investment climate is still not conducive for firms to decide and invest in innovation inputs. The result shows a lack of finance, an obstacle in international trade, and a lack of skilled workers. However, government capability seems to be improved since government regulations and telecommunication services help support firms' R&D activities. The competitive environment is favorable to promote firms' investment in innovation activities because the result shows a positive relationship between demand increasing in domestic and international markets and the extent of informal competition as a constraint and the R&D investment or innovation outcomes.

To improve the R&D activities and innovation outcomes, firms need to invest in complementary factors, such as internationally-recognized certification, foreign technology license, and new machinery and equipment. The result shows that the firms that invest in internationally-recognized certification tend to invest in R&D and produce product innovation. This relationship also happens to firms with foreign technology licensing and a new tangible asset.

Even though R&D impacts the likelihood to produce innovation outcomes, which, in turn, helps improve firm productivity, there are complementarity factors, such as physical capital and human capital, that make innovation outcomes and upgrade firm productivity in the different stages of the innovation process. The R&D investment's predicted value positively impacts a firm's propensity to introduce innovation outcomes. The larger firms, importers, firms with certification, and firms with foreign technology licenses tend to implement organizational innovation, while foreign-owned firms tend to introduce product innovation. Besides, firms with competitive pressures from local and international markets also tend to make product innovations. Firms choosing to invest substantially in staff training to upgrade their human capital are likely to produce product and organizational innovations.

Technological cooperation indicator shows the weak linkage between firms and other firms or public institutions, suggesting the limited management capability among Cambodian firms. By technological cooperation, we mean how firms connect with other firms or public institutions to learn new technologies related to product and process innovations. When it impacts only process innovation, Cambodian firms may invest in new machinery and equipment and interact with international suppliers to learn the embedded technologies. Also, this can be interpreted that firms or public institutions have limited management and technological capabilities, so they are reluctant to interact to develop product innovation. Cambodian NIS relies on the private sector, especially foreign firms, to interact with domestic firms as subcontracting to provide product standards and propose Cambodian firms to make products following the standards. This interaction reveals fewer opportunities for Cambodian firms to learn new knowledge and technologies from foreign firms. The current finding can be used to explain this interaction approach. While firms with subcontracting tend to produce product and organizational innovations, firms that interact with clients and suppliers using email and websites to get information sources tend to develop product innovation.

Finally, the predicted value of product innovation has a positively significant relationship with labor productivity, while the predicted value of organizational innovation has a negatively significant relationship with it. Besides, firms with increasing physical capital also tend to improve the labor productivities. Product and process innovations are complementary, but the product and organizational innovations or process and organizational innovations substitute.

Chapter 4 will be organized as follows. Section 4.1 will focus on the literature review on the innovation complementarities' role in increasing the firm productivity growth, while section 4.2 on the link between innovation and productivity in the CDM model. In section 4.3, the econometric model will be specified, and the data set and descriptive statistics will be described to understand the research methodology and the whole picture of the Cambodian NIS. Section 4.4 will explain the econometric results by discussing them with previous empirical studies and the economic theory related to the NIS. Sensitivity analysis will be conducted to understand the direct and indirect impacts of the variables related to foreign direct investment, international integration, demand-pull factors, competitiveness, and technology-push factors on R&D and innovation outcomes. A robustness check will be done to compare the present econometric result with those using the IV estimation method applied by Griffith et al. (2006) and the SEM estimation method applied by Cirera et al. (2016a). Finally, section 4.5 will conclude.

4.2 The Role of Innovation Complementarities in the Growth of Firm Productivity

4.2.1 Complementary Factors in Producing Innovation

In the production function, the firm needs complementary factors, such as physical capital, human capital, and management capabilities, in addition to R&D activities to produce new products and processes. When developing countries commonly don't have adequate stock of complementary factors, they cannot obtain a higher return from the increasing R&D investments (Maloney, 2017). Similarly, Cirera et al. (2017) found that there is a complementarity between factors of production. Particularly, firms need machinery and equipment, well-trained workers, organizational techniques, R&D capabilities, and learning capabilities to produce innovation outcomes and firm productivity growth.

In the concept of ‘Expanded NIS’ proposed in Chapter 2, firms tend to access the innovation inputs at a higher cost and reduce their profits when they counter-face with the barriers in the accumulation of all types of capital. The firms are difficult to increase their firm productivity when they cannot access financing to invest in the machinery and equipment, which is an important part of the learning processes. Also, the firms usually hesitate to invest in innovation activities when facing an adverse business climate, which increases the cost of doing business. Besides, firms hesitate to commit their long-term innovation projects when facing the regulatory climate's uncertainty. In addition, they tend not to cooperate in innovation activities when lacking the rule of law resulting in an adverse contracting environment. Another barrier is the business entry and exit. The firms are not likely to invest in all types of capital when facing more stringent procedures to start the business or to file for bankruptcy. Finally, firms need favorable macroeconomic and framework conditions to accumulate the innovation inputs and upgrade their capabilities. The macroeconomic and framework conditions include a stable macroeconomic context, appropriate competitive structure, suitable trade regimes, and international networks.

Also, firms confront barriers to accumulating knowledge capital. Those barriers include labor market regulation rigidities, lack of seed and venture capital, and inability to exploit innovation externalities. Labor market rigidities restrict the technology transfer through the limited mobility of well-trained workers. The lack of seed and venture capital impedes the startups and existing innovative firms from investing in the long-term innovation projects. Another barrier is the lack of the intellectual property right regime to resolve the innovation externalities. To accumulate the innovation inputs, the government needs to fix the absence of these complementary factors by resolving not only the barriers related to the knowledge capital accumulation but also the business environment's obstacles, which impede the accumulation of physical capital and human capital.

In recent literature, there appears that the concept of complementarities in innovation policies promotes firms to innovate or increase innovation intensity. According to Mohnen et al. (2005), there are complementarities in various innovation policies, such as finance, skilled labor force, opportunities for external collaborations, and reduced regulatory burden, in promoting the firms to innovate. Suppose the government wants to increase the innovation investment intensity. In that case, it needs either policies to facilitate access to finance, provide a skilled labor force, promote external collaborations, or reduced regulatory burden. This finding suggests that to encourage the firms to innovate, the government needs a package of policies; however, to encourage the firms to increase the innovation investment intensity, it needs even more targeted innovation policies.

4.2.2 Complementarity of Innovation Inputs in Producing Innovation Outputs

Innovation inputs range from human and organizational capital to more advanced R&D. They need to be accumulated and complemented with one another to produce innovation outcomes. These innovation outcomes include new or improved products and services, new business processes, new work organizations, new marketing methods, or new intellectual property patents (Cirera et al., 2017; Cirera et al., 2016b, p. 4-6). The development of these innovation outcomes requires technology, equipment, physical production facilities, and assets, such as human capital, R&D, software and databases, intellectual property use, and organizational capital (Cirera et al., 2017). To develop these innovation inputs, firms also need to invest in some innovation activities depending on innovation outcomes' technological sophistication. While firms invest in R&D, software and database, patents, and technology licenses to develop scientific and innovative capital to produce technological innovation, they invest in managerial and organizational capital, such as business models, design and prototyping, and corporate alliances and networks, to produce organizational innovation.

The quality of the innovation outcomes depends on the firms' learning and management capabilities, which are different depending on the contexts of the sector, country, enabling environment, and policy framework. In the NIS approach, firms need adequate human capital supplied by the national education system. They also need to upgrade management and production capabilities supported by the firm capability upgrading system. It includes the business support services, such as productivity and quality extension services, process and best practice dissemination services, and advanced consulting services. Firms need to cooperate with institutions and other firms to produce innovation outcomes while subcontracting with exporting firms to supply intermediate or final products. Through this subcontracting, they can learn new knowledge and technologies from the exporting firms. They also need to contact suppliers to access technical expertise and clients to access new market knowledge to produce product innovation.

4.2.3 Combination of Innovation Outputs in Increasing Firm Productivity Growth

While technological innovation is vital to promote economic development, firms also need organizational innovation to diffuse it inside and outside the firms. This diffusion is made through interaction within firms and between firms and other firms or external knowledge infrastructures such as universities and R&D institutes (Lundvall, 1992 and 2010a). Freeman (1988) also found that workplace organization plays an essential role in promoting Japanese firms to adopt new technologies through interaction within firms and between firms and other firms or external knowledge infrastructure.

Many researchers have recently been studying organizational and marketing innovations and their combination with technological innovation in producing firm productivity growth. According to Mohnen et al. (2013), all four types of innovation outcomes, namely product, process, organizational, and marketing innovations, contribute to improving the firm productivity growth. They also have the combination of innovation outcomes in various forms to impacts productivity growth.

The combination of innovation outcomes relies on the country context. Polder et al. (2010) found that organizational innovation has the most significant impact on Sweden's productivity.

Product and process innovations are complementary, and they have a positive effect on productivity when combined with organizational innovation. However, product and organizational innovations substitute. Process and organizational innovations are complementary and have a positive impact on productivity.

In contrast, Ballot et al.'s (2011) result is different from Polder et al. (2010). In the UK and France, product innovation complements organizational innovation in the absence of process innovation. Also, product and process innovations are complementary when organizational innovation does not exist. Another difference is that process and organizational innovations substitute with each other. This finding implies that process and organizational innovations have the same performance effects. However, when comparing France with the UK, the result shows that both countries have the same combination of innovation outcomes and have no substitution effect. However, there is no combination between product and organizational innovations in the UK.

The combination of innovation outcomes also relies on the firms' resources and capabilities. High R&D firms tend to invest in both product and organizational innovations no matter how process innovation is present or not, while product and process innovations complement each other in the absence of organizational innovation. In contrast, firms with lower capabilities tend to substitute product and process innovations when organizational innovation is absent.

4.3 The Link between Innovation and Productivity in the CDM Model

To study the link between innovation and productivity, most researchers applied the CDM model proposed by Crépon, Duguet, and Mairesse (1998). The authors used the data from the innovation survey of French manufacturing conducted during 1986-1990, the Annual Survey on Research, and the Annual Firm Survey to study this relationship. In the original CDM model, R&D capital is endogenous to the innovation equation, and innovation output is endogenous to the productivity equation.

To resolve the selectivity and simultaneity bias, they use the generalized Tobit specification for the R&D investment. They apply the count data specification for patents and ordered probit specification for the interval data on the share of innovative sales. In this case, asymptotic least square (ALS) is the more appropriate estimator than the general method of moments (GMM) for three reasons. First, ALS is more efficient in the case of large samples. Second, ALS is less computational cost than GMM because when GMM and ALS involve two steps, GMM needs the full sample in the second step while the latter requires only a subsample. Third, ALS is an ideal method since it is easily used to generalize the nonlinear system by extending the framework to estimate the limited dependent variables system. Besides, even though the full-information maximum likelihood (FIML) estimator is more efficient than ALS, at that time, it is not practicable due to the high computational cost.

The structural equation system has three stages. The first stage includes the selection equation and R&D intensity equation. The second stage consists of the patent equation and innovative sales equation, and the last step is the productivity equation.

Selection Equation

$g_i^*=x_{0i}b_0+u_{0i}$ (1)

Where g_i^* is the latent dependent variable of firm i. x_{0i} and b_0 are the explanatory variables' vector and the associated coefficient vector, respectively. Whereas u_{0i} is the error term capturing the unobserved factors.

$g_i=1$, if $g_i^*>c$ (threshold)

$g_i=0$, otherwise.

R&D Intensity Equation

$k_i^*=x_{1i}b_1+u_{1i}$ (2)

Where $k_i^*=k_i$, if $g_i^*>c$; but $k_i=0$, otherwise. They assume the joint normality of the two equations:

$$\begin{pmatrix} u_{0i} \\ u_{1i} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_0^2 & \rho\sigma_0\sigma_1 \\ \rho\sigma_0\sigma_1 & \sigma_1^2 \end{pmatrix}\right)$$

Where σ_0 and σ_1 are the standard errors of u_{0i} and $u_{1i,}$ and ρ is their correlation coefficient. Variances are $\sigma_0^2=1$ and σ_1^2

Patent Equation

$n_i^*=E(n_i|k_i^*, x_{2i}, u_{2i}, \alpha_K, b_2)= \alpha_K k_i^*+x_{2i}b_2+u_{2i}$ (3)

Where n_i^* is the expectation of the number of patents given the latent variable k_i^* and other explanatory variables x_{2i}.

Innovative Sales Equation

$t_i^*= \alpha_K k_i^*+x_{2i}b_2+u_{2i}$ (4)

t_1^* is the underlying (unobserved) or true value of the share of innovative sales expressed in the logarithm. They assume that u_{2i} is normal $(0, \sigma_2^2)$

Productivity Equation

$q_i=\alpha_I \ln(n_i^*)+x_{3i}b_3+u_{3i}$ (5) or

$q_i=\alpha_I t_i^*+x_{3i}b_3+u_{3i}$ (6)

Where q_i is the labor productivity expressed as the logarithm of the value-added per worker, x_{3i} is the vector of the explanatory variables, b_3 is the corresponding coefficient vector, and u_{3i} is the error term capturing the unobserved factors.

Later, many researchers have adopted the CDM model, but they have adjusted it according to the economic theories and the availability of the data set. Griffith et al. (2006) used this model to study the link between innovation and productivity across four European countries: Britain, France, Germany, and Spain. Their structural model applies a three sub-sequential step procedure, even though it is less efficient. First, the generalized Tobit estimator is applied to the binary probit R&D decision and R&D intensity equations using the maximum likelihood estimation method. Second, predicted R&D intensity is treated as endogenous to the four innovation equations. In this case, product and process innovations equations are suitable with the binary probit specification. On the other hand, the generalized Tobit specification is applied with the share of innovative sales new to the firm and new to the market. Finally, the predicted value of innovation outputs is treated as endogenous in the productivity equation. However, this model has no simultaneity and feedback.

Many researchers have adopted the adjusted CDM model proposed by Griffith et al. (2006). Hall et al. (2008) studied this relationship on Italian SMEs, while Waheed (2012) analyzed it by comparing manufacturing firms in Bangladesh and Pakistan. Cirera (2016) checked it on manufacturing firms in Kenya. However, they applied different estimation methods in each stage of the CDM model. For the first stage, Hall et al. (2008) used the non-parametric test to test the selection equation to know whether it has a selectivity bias or not. If the test is not significant, it means that the selection equation has no selectivity bias. So, they can run the regression of R&D intensity equation applying the OLS regression estimation. While Waheed (2012) estimated the relationship between R&D decision or R&D intensity and its determinants using the generalized Tobit model, Cirera (2016) uses the probit model for R&D decision and the Poisson model for R&D intensity according to the nature of the data.

For the second stage, Hall et al. (2008) and Waheed (2012) used predicted R&D intensity as endogenous in the innovation equations, designed as the binary probit models of producing the product innovation and process innovation separately. Cirera (2016) used the multivariate probit framework to estimate product, process, and organizational innovations equations to correct the correlation of their error terms. For the third stage, all of them use the OLS estimation to run the productivity equation by treating the predicted probability of product, process, and organizational innovations as endogenous. Like Griffith et al. (2006), this modified CDM model has no feedback or simultaneity. This weakness opens for new researchers to find new estimation methods to analyze their data.

Several researchers use structural equation model (SEM) and generalized structural equation model (GSEM) estimation methods proposed by Roodman (2011). Cirera et al. (2016a) applied SEM estimation method in STATA, which uses FIML estimation method, allowing the correlation of error terms of all the equations in the structural equation system. For robustness check, their econometric results have been compared with those from the instrumental variable (IV) estimation method applied in Griffith et al. (2006).

On the other hand, Polder et al. (2010) used a generalized structural equation model (GSEM) in the second stage of the CDM model. The R&D and information and communication technology (ICT) decision equations are estimated using the probit model. In contrast, R&D and ICT intensity equations are estimated using the type II Tobit model. In step two, R&D and ICT intensity are treated as endogenous in innovation output equations. The three innovation output equations are estimated using the GSEM as the trivariate probit model, which allows the correlation of their error terms. Then, to understand the combination of innovation outcomes, seven varieties of combinations are created using non-innovative firms as the reference category. They are then used to replace the predicted values of the three types of innovation outputs in the multivariate probit model for the estimation. The productivity equation has the predicted values of innovation outcomes as endogenous and is estimated using the OLS regression model.

Baum et al. (2017) introduced GSEM, which can be used to estimate the relationship of R&D intensity, innovation, and productivity equations as a single equation. GSEM can be applied with various endogenous variables on left side of the structural equation system. Those endogenous variables include type II Tobit, probit, multinomial probit, ordered probit, and OLS regression models. In their model, latent variables appear on the right side of the first three equations. They are treated as the observed variables, which can be used to explain the unobserved factors in those equations. While the selection equation can be estimated using the full sample, the three following equations can be estimated using the available subsamples. In the three following equations, predicted R&D intensity is treated as endogenous in the innovation output equations, and predicted innovation outputs, in turn, are treated as endogenous in the productivity equation. They are the subclass of the recursive mixed-process simultaneous system. Baum et al. (2017) used the FIML estimator to estimate the structural parameters of a seemingly unrelated equation (SUR) system, including those parameters that vary across sectors. Furthermore, it allows for the cross-correlation of disturbances in the four-equation system.

In terms of R&D intensity, its predicted value is correlated with innovation outputs in terms of the number of patents and the share of innovative sales (Crépon et al.,1998); innovative sales (Baum et al., 2017), product innovation (Polder et al., 2010). It also impacts product and process innovations (Hall et al., 2008; Cirera et al., 2016a; Griffith et al., 2006), labor productivity in Germany, innovative sales new to the market in the case of Germany and the UK (Griffith et al., 2006). However, it is not the case for France for innovative sales new to the firm. In terms of productivity, it is significantly correlated with innovation outputs in terms of the number of patents and the share of innovative sales (Crépon et al.,1998), product and process innovations (Griffith et al., 2006, Hall et al., 2009, Waheed, 2012). It also affects organizational innovation, the combination of product and process innovations, and the combination of product and organizational innovations (Polder et al., 2010).

Firm size is an important determinant and varies in its relationship with R&D, ICT, and innovation outcomes among studies. Firm size has a significant impact on the R&D engagement (Crépon et al.,1998; Baum et al., 2017), R&D intensity (Cirera, 2016), ICT (Cirera et al., 2016a), product and process innovations (Hall et al., 2008; Waheed, 2012,), product innovation (Cirera, 2016). However, it is negatively associated with R&D intensity (Hall et al., 2008). This negative impact may derive from the fact that Italian SMEs play a more critical role than large firms to conduct R&D activities to produce new products or processes. Foreign ownership is not likely to invest in R&D in Kenya. However, when R&D definition is widened to include machinery and equipment and staff training, it positively impacts the R&D. This may derive from the fact that multinational firms invest in machinery and equipment as well as staff training in their subsidiaries outside Kenya rather than inside the country (Cirea, 2016). Foreign ownership positively impacts the propensity to invest in innovation inputs and innovation outputs (Baum et al., 2017), R&D intensity, and ICT (Cirera et al., 2016a). Market share is found to have a positive relationship with R&D engagement, R&D intensity

(Crépon et al., 1998), likelihood to have both innovation inputs and innovation outputs (Baum et al., 2017). However, it has a non-significant relationship with R&D intensity in the study of Cirera (2016).

The demand-pull factors impact R&D engagement, R&D intensity, and innovation outcomes (Crépon et al., 1998). However, in other studies, they are expressed in other variables. Cirera (2016) defined a two-way trader, demand decreasing within the last three years, and a market share of three years ago as the demand-pull factors. On the other hand, Cirera et al. (2016a) defined them as market share change, external market (importer and exporter), and informal sector competition. The two-way trader impacts R&D intensity (Cirera, 2016). The importer impacts R&D and ICT (Cirera et al. 2016a), innovation outcomes (Waheed, 2012). The export intensity is significantly related to the propensity of R&D investment decision, and the latter variable increases in the firms that treat the international market as their primary market. R&D intensity rises in France, Germany, and Spain, but not in the UK due to the exposure to the global markets in the former three countries (Griffith et al., 2006). Simultaneously, the demand-decreasing variable impacts the likelihood of making product innovation, and informal sector competition affects developing process innovation.

Similarly, technological push factors are defined differently in different studies. When they are measured as the degree of their importance on developing innovations, they are positively correlated with R&D engagement, R&D intensity, and innovation outcomes (Crépon et al., 1998). Cirera et al. (2016a) defined internationally-recognized certification, foreign technology license, and whether the firm invests in new machinery and equipment in the previous year as the technological factors. They found that the former two variables impact only the ICT index, while the latter affects both R&D intensity and ICT index. New machinery and equipment investment matters more for process innovation than product innovation (Hall et al., 2008). Process innovation substantially impacts labor productivity when associated with an investment in new machinery and equipment.

Investment climate variables are also defined differently by different authors. Cirera (2016) described the investment climate variables as access to finance obstacle, trade costs obstacle, telecommunication obstacle, governmental regulations obstacle, and educated workforce obstacle. The result shows that investment climate is not conducive to innovation performance since firms that perceive financing constraints tend to reduce R&D. Other variables reveal nonsignificant except government regulations obstacle that shows a positively significant relationship with R&D engagement. Similarly, Cirera et al. (2016a) found that barrier in financing makes a firm decrease their R&D but increase their ICT. However, the high percentage of workers with high school education induces firms to invest in both R&D and ICT. Similarly, an educated workforce tends to encourage firms to produce innovation outcomes (Waheed, 2012).

In terms of capital intensity, it positively affects process innovation (Cirera, 2016) and labor productivity (Cirera, 2016; Cirera et al., 2016a; Waheed, 2012). The labor force affects ICT, R&D, process innovation, and labor productivity (Cirera et al., 2016a). From the networking perspective, R&D intensity rises in France, Germany, and Spain, but not in the UK due to the cooperative arrangement on innovation (Griffith et al., 2006). Firms interacting with international clients using the internet tend to improve labor productivity. ICT positively impacts all types of innovation outcomes in the manufacturing and service sectors (Polder et al., 2010). Complemented with R&D, ICT also has a significant impact on producing innovation outcomes. Furthermore, ICT also has an indirect effect on firm productivity when used as the enabler to create product innovation new to the national or international market, which has been used to increase labor productivity.

4.4 Research Methodology and Data

4.4.1 The Model: Econometric Specification and Definition of Variables

I propose the concept of an expanded NIS suggested in Chapter 2 as the conceptual framework to adjust the original CDM model. In the expanded NIS, two implications have been proposed to cope with the innovation paradox in developing countries like Cambodia.

1. NIS should be expanded to include the broader complementary factors and institutions since firms

need not only R&D activities but also their complementary factors, namely physical capital, human capital, and learning and management capabilities, to pursue and commercialize the innovation projects.

2. Innovation cannot be solely supply-driven. It is also demand-driven since firms need to have the capabilities to innovate. Policymakers need to address the market failures and the problem of a wide range of markets to realize R&D's potential return. This goal can be achieved by improving the business environment, including setting the incentives and relaxing the firms' barriers to accumulating physical, human, and knowledge capital. Those incentives include stable macroeconomic context, encouraging competitive structure, facilitating trade regimes, and international networking. The barriers include the lack of credit, business entry and exit problems, inconducive business and regulatory climate, and lack of the rule of law.

In the traditional NIS, the national education system plays the role of supplying human capital. The firm capability upgrading system includes productivity and quality extension services, process and best practice dissemination, and advanced consulting services. They play an important role in developing the firms' management and technological capabilities. Furthermore, the national science and technology system is required to support domestic firms' R&D activities by promoting cooperation with institutions and other firms to produce technological innovation. Another form of collaboration is the subcontracting between domestic firms and exporting firms to supply intermediate goods or final products, so the former can learn the new knowledge and technologies from the latter.

To analyze the link between R&D, innovation, and productivity, Crépon et al. (1998) developed a CDM Model. It is a recursive structural equation system using ALS, which is a minimum distance estimator. The ALS estimation method is used to estimate because it is more efficient and less computational than GMM with large sample size. Furthermore, FIML is more efficient than ALS, but its computation cost is relatively high and impractical earlier.

We use GSEM because we have a small sample size in the present model. Moreover, with faster computers and recent advances in numeric simulation techniques, we can apply the FIML estimation method with a low computational cost (Roodman, 2011). Besides, GSEM is the observed recursive mixed-process model, which can be applied with various kinds of endogenous dependent variables such as Tobit, probit, multinomial probit, ordered probit, interval regression, and OLS regression models. Recently, it has been applied by several researchers. For example, Baum et al. (2017) used it to analyze the relationship between R&D, innovation, and productivity in Sweden.

After obtaining the econometric result using GSEM, sensitivity analysis will be conducted to understand the direct and indirect impacts of variables related to FDI, international integration, demand-pull factors, competitiveness, and technological push factors on firms' innovation performance. Besides, a robustness check will be done to compare the result using GSEM with the work using the IV estimation method applied in Griffith et al. (2006) and using the SEM estimation method applied in Cirera et al. (2016a).

Innovation Inputs Function:

There are four equations. The first two equations explain the determinants of R&D decision and innovation investment decision, while the other two equations explain the determinants of R&D intensity and innovation investment intensity. Since R&D investment in Cambodia is small and may not significantly impact innovation outcomes and firm productivity, we suggest innovation investment as the extension of R&D's definition by adding investment in machinery and equipment to the R&D expenditure. Cirera et al. (2017) found that R&D investment and machinery and equipment investment complement each other to produce new knowledge and technologies.

We use the censored Tobit II model (Heckman, 1976) to solve the selectivity bias in R&D intensity equations since many non-performing R&D firms participated in the observations. This method divides the censored Tobit II model into two steps: R&D decision, which uses the binary probit model, and R&D intensity, which uses the OLS regression estimation. We analyze the non-parametric test by running the probit regression of the R&D decision equation to solve the selectivity bias. After that, we calculate the predicted probability of R&D engagement, inverse mills ratio, their square values, and their interaction term. Then, we run the OLS regression of R&D intensity on its determinants and the above-calculated values. The result shows that none of these values significantly impact R&D intensity, suggesting no selectivity bias (Table A.4.1). In this case, we use OLS regression to estimate equation (3) in the CDM model's first stage.

Selection equation:

RD_i^* is the latent dependent variable, shown as the following:

$RD_i^* = \beta_1 X_{1i} + \varepsilon_{1i}$ (1)

Where X_{1i} and β_1 is the vector of the determinants of the R&D intensity and vector of the coefficients, respectively. ε_{1i} is the error term, which captures the unobserved variables. We assume that the firm will decide to invest in the R&D project if its latent variable RD_i^* exceeds the industry threshold c. So, we will have the binary probit model of the R&D decision as follow:

$RD_i = 1$, if $RD_i^* > c$

$RD_i = 0$, if $RD_i^* \leq c$

R&D intensity equation:

$RDS_i^* = \beta_2 X_{2i} + \varepsilon_{2i}$ (2)

$RDS_i = RDS_i^* = \beta_2 X_{2i} + \varepsilon_{2i}$ if $RD_i=1$

$RDS_i=0$ if $RD_i=0$

However, when threshold c is unknown, c is anticipated to be equal to the minimum order statistic of the subsample of the dependent variable, RDS_1 (Zuehlke, 2003). The traditional research method is used to estimate the intensity equation by treating the threshold c to be equal to zero, while it is actually the positive value. This common fault makes the estimation to be biased by increasing the value of coefficients. To resolve this bias, we need to withdraw the threshold c or RDS_1 from the observed dependent variable before we estimate the intensity equation, as shown in the following form of the equation:

$rds_i = rds_i^* = \beta_2 X_{2i} + \varepsilon_{2i}$ when $RD_i=1$ and zero otherwise (3)

where $rds_i=RDS_i-RDS_1$ and $rds_i^* = RDS_i^* - RDS_1$

The dependent variable of equation (1) is the R&D decision or innovation investment decision, while the dependent variable of equation (3) is R&D intensity or innovation investment intensity. The determinants of the two dependent variables above are the same. However, when R&D decision or intensity is present in the innovation input equation, a variable called new capital is included in its determinants.

The explanatory variables are classified into four categories: firm characteristics, demand-pull factors, technology push factors, and the overall investment climate. The firm characteristics include firm size, a firm with foreign ownership, and whether the firm integrates into international markets, such as importer, exporter, and two-way trader. The demand-pull factors are characterized by the market share of three years ago and whether market demand increased in the domestic or international market over the last three years. Another kind of demand-pull factor is the extent to which the firm perceives the informal sector as its major competitor. Technology push factors can be proxied by whether the firm has an internationally-recognized certification and whether it is using technology licensed from foreign-owned firms. The overall investment climate includes the barriers in accessing finance, trade costs, telecommunications, and various government regulations. The government regulations include tax rates, tax administration, business licensing and permits, political instability, and corruption. The determinants also include sector dummies.

X_{1i} = Size, Foreign Ownership, Market Share, Demand Increasing, Two-Way Trader, Only Importer, Only Exporter, Extent of Informal Competition, Certification, Foreign Technology Use, Lack of Finance, Trade Costs Obstacle, Telecommunications Obstacle, Government Regulation Obstacles, and Sector Dummies.

Innovation Output Function:

The innovation function is divided into three separate innovation equations: product innovation, process innovation, and organizational innovation.

$Prod_i^* = \beta_3 x_{3i} + \varepsilon_{3i}$ (4)
$Proc_i^* = \beta_4 x_{4i} + \varepsilon_{4i}$ (5)
$Org_i^* = \beta_5 x_{5i} + \varepsilon_{5i}$ (6)

Each of them has the value of one if the condition is true; otherwise, it is zero.

$Prod_i = 1$ if $Prod^*_i = \beta_3 x_{3i} + \varepsilon_{3i} > 0$, and 0 otherwise (7)
$Proc_i = 1$ if $Proc^*_i = \beta_4 x_{4i} + \varepsilon_{4i} > 0$, and 0 otherwise (8)
$Org_i = 1$ if $Org^*_i = \beta_5 x_{5i} + \varepsilon_{5i} > 0$, and 0 otherwise (9)

Since firm simultaneously decides to produce innovation outcomes, we use a trivariate probit model to estimate its propensity to perform product, process, and organizational innovations. In addition to the predicted value of innovation inputs, the determinants of innovation outcomes include firm size, capital intensity, technological cooperation, subcontracting, connection with suppliers and clients using email and website, perception of an inadequately educated workforce, staff training, and industry dummies.

Productivity Function:

We use Cobb Douglas production function with labor (L), capital (K), and innovation outcomes (H) to explain the relationship between innovation and productivity. Mohnen et al. (2013) found that these innovation outcomes have complementarity effects on firm productivity.

$$Y = f(K, L, H)$$

$$Y_i = H_i K_i^{\alpha} L_i^{\beta}$$

$$\frac{Y_i}{L_i} = \frac{H_i K_i^{\alpha} L_i^{\beta}}{L_i} \frac{L_i^{\alpha}}{L_i^{\alpha}}$$

When we transform it into the form of logarithm and add the sector controls X_i, it will appear as the following productivity equation:

$$\text{Log}\left(\frac{Y_i}{L_i}\right) = \delta_0 + \delta_1 \log(H_i) + \alpha \log(K/L_i) + (\alpha+\beta-1)\log(L_i) + \delta_2 X_i + \varepsilon_{6i}$$

$$\text{Log}\left(\frac{Y_i}{L_i}\right) = \delta_0 + \delta_1 Pr\hat{o}d_i + \delta_2 Pr\hat{o}c_i + \delta_3 O\hat{r}g_i + \delta_4 \log(K/L_i) + \delta_5 \log(L_i) + \delta_6 X_i + \varepsilon_{6i}$$

The determinants of productivity are the predicted values of innovation outcomes, capital intensity, firm size, and sector dummies.

We assume that ε_{1i}, ε_{3i}, ε_{4i}, ε_{5i}, and ε_{6i} are multivariate normal distribution with mean zero and variance $\sum$. The GSEM is estimated by using Geweke-Hajivassiliou-Keane (GHK) simulated maximum likelihood.

4.4.2 Data

Enterprise surveys were implemented in 148 countries at 155,000 firms (World Bank, 2016). The enterprise surveys in 139 countries were designed to adapt to the global methodology, in which their data sets can be analyzed and used to compare across the nations and times. Enterprise Survey Cambodia 2016 was conducted from March to June 2016 on a sample of 373 firms. Stratified random sampling has been applied to choose the sample as the weight between firm sizes, industries, and regions. There are several reasons to support the use of stratified random sampling rather than simple random sampling. First, it helps obtain an unbiased estimation of the population's subdivision and the total population. Second, it includes representative firms in different firm sizes, industries, and regions in the sample. Third, it can be used to estimate to get smaller standard errors better than a simple random sample. Finally, it can be estimated to obtain a smaller error bound than a simple random sample when the sample size is the same and the strata measurements are homogeneous. The population of firms includes firms in sectors, such as manufacturing (group D), construction (group F), services (groups G and H), transport, storage, and communications (group I), and IT (subsector of group K). However, they exclude financial intermediation (group J), real estate and renting activities (group K), the agriculture, public sector, and utility.

The enterprise survey was conducted to collect the data related to firms' characteristics, balance sheet, cost of inputs and labor, innovation and technology, factors impacting firm growth and performance, job creation, and firms' experience about the business environment (Cirera et al., 2016b,

p. 9-11). Obtaining this information, we can estimate the relationship between investment climate, innovation, and firm performance and compare the innovation system across countries and times. These research results can help evaluate the effectiveness of the innovation policies to upgrade the national innovation system. The innovation module incorporated in the enterprise survey is adapted to the Oslo manual framework. While Enterprise Survey Cambodia 2013 adopted only nine questions related to innovation and technology, Enterprise Survey Cambodia 2016 adopted 19 items. The additional questions were prepared to ask for more information to clarify the yes/no questions in the questionnaires in both periods (World Bank, 2016). For example, suppose the yes/no questions in the short questionnaire series were asked whether they introduced the new or significantly improved products and services in the last three years. In that case, the additional questions were asked about whether they were new to the main market and what the percentage of their total sales was. They were also asked what their main characteristics of the new products or services were, what their collaboration was, and whether they used to abandon or suspend before completion or still ongoing in the current fiscal year.

4.4.3 Descriptive Statistics

Firms invest in innovation inputs such as R&D, machinery and equipment, staff training, and new tangible and intangible assets to produce innovation outcomes in the forms of product, process, and organizational innovations. Firm capabilities in management competency and technical literacy are essential to combine innovation and other exogenous variables to produce a high quality of innovation outputs. In turn, innovation outputs help upgrade firm productivity, proxied by sales per worker or labor productivity (Cirera et al., 2017; Crépon et al., 1998).

Table 4.1 shows the descriptive statistics that can explain the big picture of the Cambodian NIS. In Cambodia, the number of firms that decide to invest in R&D is around 10% of sample firms. While the definition of R&D investment is extended to include machinery and equipment investment, the incidence increases to about 37% of sample firms. In terms of intensity, Cambodian firms spend a little on R&D that may slightly impact innovation outcomes and firm productivity; that's why R&D definition is extended to include also machinery and equipment, hereafter called innovation investment.

The determinants of the decision and intensity of R&D and innovation investment are classified as the characteristics of firms, demand-pull factors, technological push factors, and investment climate variables (Cirera et al., 2016a; Cirera, 2016). In the firm characteristics variable group, there are many variables. The larger the firm size, the greater the amount of R&D expenditure the firm tends to invest. Cambodia can attract many multinational firms to locate in the country, and these firms use it as the export platform among Cambodian firms (OECD, 2018a). Foreign-owned firms represent about 10% of the sample firms, while two-way traders, only exporters, only importers account for 22%, 8%, and 11% of the sample firms, respectively. Small firms used as a base category of firm size represent 50% of the sample firms, while medium- and large-sized firms account for 32% and 17% of the sample firms, respectively. In the demand-pull factors, international and domestic market competitions play the crucial incentives for firms to invest in innovation inputs to produce innovation outcomes. Meanwhile, firms that experience their market demand increasing represent about 63% of the sample firms, and informal competition scales at around 1.5. These figures suggest that Cambodian firms are confronting both international and domestic competitive environments strongly. On the other hand, demand increasing and market share encourages firms to diversify their products and markets, thus promoting firms to increase innovation inputs.

In technological push factors, firms with internationally-recognized certification represent about 5% of the sample firms, while firms using foreign technology licenses account for about 8%. Furthermore, firms investing in new physical capital represent 31% of the sample firms. These proportions suggest that most Cambodian firms choose their learning strategies by investing in these three external sources of technical knowledge, encouraging them to invest directly in more innovation inputs to develop the innovation outcomes indirectly.

The investment climate variables are measured as a Likert scale, which 0 represents the lowest obstacle, and 4 represents the highest obstacle. Their scales staying at slightly more than one indicate that the business environment is favorable due to the low level of obstacles in access to finance, trade costs, telecommunications, and government regulations. The improved investment climate helps Cambodia attract domestic and foreign direct investments to start and run their businesses and encourage domestic firms to invest in the innovation inputs.

Cambodian firms that report performing product, process, and organizational innovations are about 26%, 31%, and 21% of sample firms. However, the reported innovation outcomes are suspected of overestimating due to the subjective bias since respondents in developing countries tend to say the small improvements in products or processes as the innovation outcomes (Cirera et al., 2017). When measuring the combination of innovation outcomes, firms with each combination represent about 5% of sample firms. However, firms investing in the three types of innovation outcomes represent only 2.4% of sample firms since they need significant financial capital, which only large-sized firms can afford to invest.

The determinants of producing innovation outputs are classified into three groups of variables: firm characteristics, networking, and human capital. The firm characteristics include firm size and capital intensity. The networking consists of technological cooperation, subcontracting, interacting with clients and suppliers using email and website. Human capital comprises perceived barriers in

Table 4.1 Descriptive Statistics and Definition of Variables

Variables	Observation	Mean	Standard Deviation	Definition
Innovation Inputs				
R&D Intensity	373	.8315	3.1231	The logarithm of the R&D expenditure per worker
R&D Investment Decision	373	.1046	.3064	Value of 1 if a firm invests in R&D
Innovation Investment Intensity	373	5.6066	7.5582	The logarithm of the investment in R&D and machinery and equipment per worker
Innovation Investment Decision	373	.3700	.4834	Value of 1 if a firm invests in R&D and machinery and equipment
Training Decision	373	.2761	.4477	Value of 1 if a firm decides to invest in staff training
Innovation Outcomes				
Product Innovation	373	.2654	.4421	Value of 1 if a firm introduces new products or services, and 0 otherwise
Process Innovation	373	.3137	.4646	Value of 1 if a firm introduces new processes, and 0 otherwise
Organisational Innovation	373	.2011	.4013	Value of 1 if a firm introduces new organizational and management practices, and 0 otherwise
Product*Process	373	.0563	.2308	Value of 1 if a firm introduces both product and process innovation, and 0 otherwise
Product*Organization	373	.0509	.2202	Value of 1 if a firm introduces both product and organizational innovations, and 0 otherwise
Process*Organization	373	.0429	.2029	Value of 1 if a firm introduces both process and organizational

				innovations, and 0 otherwise
Prod*Proc*Org	373	.0241	.1537	Value of 1 if a firm introduces three types of innovation outcomes and 0 otherwise
Productivity				
Sales per Worker	373	17.499	1.5650	The logarithm of sales per worker
Enabling Environment				
Lack of Finance Obstacles	373	1.1254	1.0402	The Likert scale ranges from 0 to 4
Trade Costs Obstacles	373	1.1116	.8098	Likert scale of transport and trade regulation ranges from 0 to 4
Telecommunications Obstacles	373	1.0894	1.0487	The Likert scale ranges from 0 to 4
Government Obstacles	373	1.0962	.6057	Likert scale of 4 factors such as tax rates and tax administration, business permits, political instability, and corruption, ranges from 0 to 4
Educated Workforce Obstacles	373	1.1035	1.1732	Likert scale range from 0 to 4
Demand-Pull Factor				
Demand Increasing	373	.6327	.4827	Value of 1 if a firm reports sales (t) minus sales (t-3) positive, 0 otherwise
Market Share	373	0.0028	0.4178	Sales (t-3) divided by total sales (t-3)
Extent of Informal Competition	373	1.4781	1.3553	It is measured by whether a firm perceives the informal sectors as its main competitors. Likert scale range from 0 to 4
Technology-Push Factor				
Certification	373	.0456	.2088	Value of 1 if a firm has an internationally-recognized certification, and 0 otherwise.
Foreign Technology Licensing	373	.0777	.2681	Value of 1 if a firm is using any technology licensing from the foreign-owned firm, and 0 otherwise
New Capital	373	.3110	.4635	Value of 1 if a firm invests in a new asset and 0 otherwise
Firm Characteristics				
Foreign Ownership	373	.0965	.2957	Value of 1 if a firm has foreign investments more than 15%, and 0 otherwise
Two-way Trader	373	.2172	.4129	Value of 1 if a firm imports and exports, and 0 otherwise
Exporter Only	373	.0804	.2723	Value of 1 if a firm only exports, and 0 otherwise
Importer Only	373	.1126	.3165	Value of 1 if a firm only imports, and 0 otherwise
Small	373	.5040	.5007	Value of 1 if a firm has employees between 5 and 19
Medium	373	.3217	.4678	Value of 1 if a firm has employees between 20 and 99

Large	373	.1743	.3798	Value of 1 if a firm has employees more than 100
Labor	373	3.1175	1.5269	Logarithm of employment
Capital Intensity	373	5.7588	7.9781	The logarithm of the capital-labor ratio
Networks				
EMAIL	373	.5603	.4970	Value of 1 if a firm uses email to contact suppliers or clients
WEBSITE	373	.2761	.4477	Value of 1 if a firm has its website
Subcontracting	373	.0697	.2550	Value of 1 if a firm exports indirectly through other firms, and 0 otherwise
Technological Cooperation	373	.1367	.3440	Value of 1 if a firm cooperates with other firms or institutions or receives support from the parent company to produce new products and processes, and 0 otherwise

Source: World Bank, 2016

access to an educated labor force and whether firms invest in staff training. For firm size and capital intensity variables, when they are increased, they tend to positively impact the production of innovation outcomes. From the networking perspective, firms may cooperate with other firms or institutions to learn new knowledge and technologies to produce innovation outputs. Cambodian firms seem to rely less on relationships with other firms and institutions since networking in subcontracting and technological innovation collaboration projects represents less than 15% of the sample firms. However, firms tend to contact clients and suppliers using email and website to ask about the product characteristics, new knowledge related to work organization, and new technologies related to production processes. For human capital, while the perceived barrier in obtaining an educated labor force stays at slightly more than one on the Likert scale from 0 for the lowest obstacle to 4 for the highest obstacle, firms don't have a problem accessing the skilled worker. However, 28% of them are committing to invest in staff training to develop their human capital, suggesting the current labor force's low skills. This implies that the Cambodian education and training system seems to be unable to supply adequate technicians, engineers, scientists, managers, and entrepreneurs to upgrade firm capabilities. Finally, innovation outcomes, together with capital intensity and labor force, help improve labor productivity. It is important to notice that the interpretation of these variables and their relationship can be characterized as the hypotheses. However, their actual impact can be measured based on running the GSEM, as shown below.

4.5 Econometric Results

4.5.1 Innovation Input Function

Table 4.2 shows the regression result on the innovation input equations. Columns (1) and (4) deliver the outcomes from running the probit regression model of innovation input decision. Columns (2), (3), (5), and (6) show the results from running the OLS regression model of innovation investment intensity. It is the result of the first stage of the CDM model. The competitive environment seems to be conducive for a firm to invest in R&D. As has been shown, firms experiencing competition from the informal sector tend to increase the R&D investment by 28% or 29% and innovation investment intensity by 45%. This finding is contrary to Cirera et al. (2016a), who found an insignificant impact. Demand increasing incentivizes the firm to increase innovation investment by about 73%.

In addition to R&D, firms need complementary factors, namely internationally-recognized certification, foreign technology licenses, and new physical capital, to produce new knowledge. When firms invest in new machinery and equipment, they tend to invest in R&D and increase their investment by about 111%, similar to Cirera et al.'s (2016a) finding. Besides, firms with internationally-recognized certifications are likely to increase their R&D investment by almost 140%

or 143% and innovation investment by nearly 219%. Also, firms with foreign technology licenses tend to increase innovation investment by 505%. This finding is similar to Crepon et al. (1998). However, it is not the case for firms in African developing countries (Cirera et al., 2016a).

The investment climate seems not to be conducive to promote R&D, even though it has been improved in general. As has been shown, international trade obstacle is likely to reduce R&D investment by 35% or 38%. According to Cirera et al. (2017), international trade obstacles such as the high cost of transport and burdensome non-tariff measures can make exporting and importing costs increase, leading to a rise in the cost of doing business and a decrease in economic profits. Therefore, firms don't have the incentives to invest in R&D. Firms with financial constraints are likely to reduce innovation investment by about 39%. This result is similar to Cirera (2016) and Cirera et al. (2016a).

However, telecommunications and government regulations show fewer obstacles, which helps increase R&D investment by about 26% and 51% or 58%, respectively. Cambodia may succeed in implementing the Telecommunication and ICT Development Policy in 2016 to upgrade the telecommunication and ICT infrastructure, supporting R&D activities and digital technological adoptions. It may charge lower tax rates, relax some rules related to business permits and licensing, or increase government efficiency, improving the macroeconomic context that induces firms to increase the R&D investment.

According to Andrews et al. (2017), the variable of obstacle in government regulations is measured as the average of "corruption," "political instability," and "government effectiveness," including "tax rate," "tax administration," and "business permits." It is also called state capability. In their study, state capability is measured as the average of the scale of world governance indicators (WGI), quality of government (QOG), and failed state index (FSI). WGI adopts three main indicators, including "government effectiveness," "law and order," and "control of corruption," while QOG adopts three main indicators, including "corruption," "law and order," and "bureaucratic quality." FSI applies the indicator of "public services," including policing and criminality, infrastructure, roads, water and sanitation, education, and health. The positively significant effect of government regulations' obstacle suggests that the Cambodian state capability has been improved significantly to promote the R&D investment in the private sector.

However, table 4.2 reveals the unimportance of firm size, foreign direct investment, international integration, and market share. Firm size is not essential to explain R&D investment variation due to Cambodia's country context. This finding is different from the case of developed countries, which show a significant impact of firm size on R&D activities (Crépon et al., 1998; Griffith et al., 2006; Baum et al., 2017); however, its impact is negative in the case of Italian firms (Hall et al., 2008). In the case of developing countries, its effect is controversial. While the impact of firm size on R&D activities is significant for Kenyan firms (Cirera, 2016) for Bangladesh and Pakistan firms (Waheed, 2012), it shows non-significant for firms in African developing countries (Cirera et al., 2016a). However, even though Firm size does not directly impact firms' R&D engagement, it significantly impacts producing organizational innovation (see table 4.3) and labor productivity (see table 4.4). In terms of FDIs and international integration, most exporters are large-sized and foreign-owned and treat Cambodia as the export platform. They import the material inputs from abroad while installing the final products and exporting them to international markets (Sokty et al., n.d). Since they invest significantly in external knowledge in the forms of internationally-recognized certification, foreign technology license, and new machinery and equipment, they don't invest much in R&D.

For example, the garment industry represents around 70% of total exports. Most garment manufacturers are foreign-owned and large-sized and don't directly contact global retailers or global branders (OECD, 2018a). They work with intermediaries who have the role to contact directly with international buyers. So, they don't need to invest in R&D but use the given internationally-recognized certifications, foreign technology licenses, and embodied technology in the new machinery and equipment to produce the final products. The large-sized local firms are not the exception. In contrast to the above result, Cirera et al. (2016a) found that foreign-owned firms and importers tend to increase R&D investment significantly. In Cambodia, firms with the given certifications and foreign technology licenses tend to invest in R&D.

As a sensitivity analysis, we added variables related to FDIs, international integration, demand-pull factors, competitiveness, and technology-push factors in the second stage of the CDM model. We found that foreign-owned firms tend to produce product innovation. On the other hand, importers tend to make organizational innovations. This finding suggests that these variables do not directly impact R&D engagement and investment but indirectly affect the likelihood of making innovation outcomes and firm productivity through the R&D intensity equation.

Table 4.2 Innovation Input Function Using GSEM

Variables	R&D Decision (1)	R&D Intensity (Bivariate) (2)	R&D Intensity (Trivariate) (3)	Innovation Investment Decision (4)	Innovation Investment Intensity (Bivariate) (5)	Innovation Investment Intensity (Trivariate) (6)
Medium	-.0301 (.2556)	-.1898 (.3660)	-.2342 (.3673)	-.1638 (.1814)	-.4134 (.4937)	-.4541 (.4959)
Large	.4365 (.3700)	-.4579 (.5324)	-.4229 (.5319)	.2559 (.2697)	.7007 (.7380)	.7523 (.7349)
Foreign Owned	-.4195 (.4805)	.2601 (.5622)	.0809 (.5718)	-.2439 (.3399)	.3473 (.8895)	.1236 (.8334)
Importer	-.1453 (.5028)	.4638 (.5434)	.8026 (.6342)	-.1555 (.3466)	-.9135 (.8747)	.0082 (.9525)
Exporter	.0374 (.3837)	.5305 (.4661)	.4284 (.4824)	-.0843 (.2864)	-.3020 (.7572)	-.4513 (.7237)
Two-Way Trader	.3256 (.6755)	.4675 (.9397)	.7622 (.8965)	-.1509 (.4989)	-.9953 (1.3488)	-.6135 (1.2904)
Demand Increasing	-.2510 (.2166)	.3409 (.2790)	.2385 (.2891)	.2200 (.1673)	.7344* (.4395)	.6523 (.4164)
Market Share	-86.7046 (117.6574)	-2.4989 (2.9829)	-3.5409 (3.0001)	12.1934 (21.5473)	3.4150 (4.5727)	.7604 (4.3197)
Extent of Informal Competition	.1485* (.0897)	.2976*** (.1024)	.2805*** (.1042)	.1233* (.0637)	.4583*** (.1736)	.4524*** (.1599)
Certification	.4371 (.4384)	1.4303** (.6040)	1.4034** (.6227)	.5560* (.3379)	2.3920** (.9329)	2.1932** (.8998)
Technology License	.3600 (.3624)	.4405 (.4702)	.7494 (.4812)		5.0088 (.94166)	5.0547*** (.9200)
New Capital	.91096*** (.2251)	1.1112** (.4533)	1.1062** (.5040)			
Lack of Finance	-.1916 (.1207)	-.1269 (.1416)	-.0927 (.1441)	-.2309** (.0882)	-.3905* (.2187)	-.2827 (.2189)
Trade Costs Obstacle	-.3669** (.1770)	-.3810* (.2078)	-.3516* (.2121)	-.0641 (.1306)	-.1417 (.3147)	-.1392 (.3008)
Telecommunication Obstacle	.0742 (.1208)	.2616* (.1474)	.2430 (.1513)	.0382 (.0867)	.0479 (.2225)	.0130 (.2163)
Government Obstacle	.3616* (.1992)	.5143** (.2597)	.5827** (.2563)	.0925 (.1471)	-.0204 (.3720)	.1572 (.3605)
Constant	-1.5227*** (.3165)	-.4849 (.4282)	-.5188 (.4298)	-.7877*** (.2354)	1.4975** (.6460)	1.3239** (.6149)
Observation	328	373	373	323	373	373
ISIC-2 digit dummy	Yes	Yes	Yes	Yes	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Compared with Cambodia, Thailand shows that importer and two-way-trader tend to invest in R&D, and a competitive environment doesn't have a significant impact on R&D investment (Table A.4.11 in appendix). Like Cambodia, Thailand relies on internationally-recognized certification and investment in new machinery and equipment to induce firms to invest in R&D. It also lacks financing to support firms to invest in it but has conducive governmental regulations for promoting R&D investment. This finding suggests that Cambodia achieves a smaller extent of international integration than Thailand. Its informal sectors are larger than Thailand, representing the larger extent of informal competition to induce firms to invest in R&D. Vietnam shows that medium-sized firms, importers, and market share have a significant impact on R&D investment. This finding may derive from the fact that Vietnam has recently increased the public support in R&D (Vo et al., 2018) to encourage SMEs to invest in R&D to exploit the large domestic market and export market. Vietnam and Cambodia similarly have large informal sectors making informal sectors become the main competitors to their formal firms. They also rely on certification, foreign technology use, and new machinery and equipment to complement their R&D investment to produce innovation outcomes and labor productivity.

In summary, Cambodia's business environment is still not favorable to promote knowledge capital accumulation, even though it has significantly been improved. Government capability has significantly been improved. It may facilitate tax payment and business permits, keep political instability under control and reduce corruption practices, encouraging firms to invest in innovation activities. The telecommunication sector has become a business enabler to promote R&D activities and digital technological adoptions. The competitive environment seems to be conducive to promote innovation activities. This improved investment climate may encourage firms to expand their operation by increasing physical capital and labor force, improving labor productivity. However, several variables show constraints, limiting the innovation activities. The financing and international trade barriers tend to decrease the R&D activities. This may partly explain the lower level of global integration of Cambodian firms into international markets, RVCs, and GVCs, compared with Thailand and Vietnam. Cambodian firms need complementary factors, including internationally-recognized certification, foreign technology license, and new machinery and equipment, to encourage them to invest in innovation activities. Lacking these complementary factors due to the shortage of financing could partly explain the low level of R&D investment in Cambodia.

4.5.2 Innovation Output Function

Table 4.3 demonstrates the regression result of the innovation output function using predicted values of R&D intensity and innovation investment intensity values. Columns (1), (2), (6), and (7) are the results of the second stage of the CDM model applying the bivariate probit of the technological innovation equation. In contrast, Columns (3), (4), (5), (8), (9), and (10) are the results that apply the trivariate probit model of the three innovation output equations. Cambodian firms are able to use R&D investment to introduce innovation outcomes. As has been shown, the R&D intensity's predicted values significantly impact a firm's likelihood to introduce both product and process innovations. When we use innovation investment intensity to analyze, it affects all types of innovation outcomes in both probit models. This finding is similar to Griffith et al. (2006) and Hall et al. (2008), studying developed countries such as Germany, France, Spain, UK, and Italy, even though the impact is smaller for the latter (Italy). However, it is different from Cirera (2016), Cirera et al. (2016a), and Waheed (2012). They studied this relationship in developing countries such as African countries and Southern Asian countries, and the result shows a non-significant or small significant impact. This finding needs to be interpreted carefully since most developing countries' innovation types are incremental innovation in nature.

From the networking perspective, firms rely on cooperation with other firms inside or outside the group rather than public institutions such as universities and public R&D institutes to introduce innovation outcomes. As has been illustrated, firms with subcontracting tend to introduce product and organizational innovations but not process innovation. Furthermore, firms interacting with clients and suppliers tend to introduce product innovation. On the other hand, technological cooperation impacts only on the probability of process innovation.

This finding is in line with the concept of NIS of Lundvall (1992). In the NIS, users of process technology need to have a relationship with their producers to get technological expertise. In contrast, producers need to contact users to obtain knowledge about new market needs and with suppliers to access the technical expertise to introduce new production processes to produce products matching the market needs. The finding that technological cooperation affects only the probability of process innovation suggests that Cambodian firms or public institutions are reluctant to interact to introduce product innovation since they have limited management and technological capabilities. In terms of firm size, large-sized firms tend to implement organizational innovation but not product and process innovations. The result shows that firms that decide to invest in staff training tend to introduce product and organizational innovations but not process innovation.

Table 4.3 Innovation Output Function Using GSEM

Variables	Bivariate Probit		Trivariate Probit			Bivariate Probit		Trivariate Probit		
	Prod_Inn (1)	Proc_Inn (2)	Prod_Inn (3)	Proc_Inn (4)	Org_Inn (5)	Prod_Inn (6)	Proc_Inn (7)	Prod_Inn (8)	Proc_Inn (9)	Org_Inn (10)
	(Using R&D Intensity)					(Using Innovation Investment Intensity)				
Predicted R&D Intensity	.2328*** (.0610)	.2350*** (.0640)	.2079*** (.0732)	.2594*** (.0520)	.1526 (.1096)					
Predicted Innovation Investment Intensity						.1022** (.0507)	.0746* (.0425)	.1065** (.0444)	.0771* (.0425)	.1231*** (.0419)
Technological Cooperation	.0234 (.1569)	1.2352*** (.2777)	.0787 (.1715)	1.1174*** (.2694)	-.3734 (.2400)	.1356 (.1987)	1.4174*** (.2212)	.1222 (.1969)	1.4017*** (.2226)	-.2514 (.2286)
Subcontract	.2584 (.2507)	.0904 (.2902)	.3610 (.2608)	.0527 (.2684)	.6704** (.2968)	.4513 (.3004)	.1989 (.3055)	.5278* (.2803)	.2091 (.2991)	.7517*** (.2679)
Email	.2246 (.1585)	-.2204 (.1914)	.3242* (.1677)	-.2927 (.1608)	.0602 (.1785)	.3318* (.1960)	-.2389 (.1998)	.4359** (.1748)	-.3054 (.1835)	.0527 (.1737)
Website	.3594** (.1705)	.1073 (.1773)	.3871** (.1737)	.1216 (.1649)	.1232 (.1687)	.4742** (.1921)	.0181 (.1890)	.4595** (.1786)	.0319 (.1877)	.0938 (.1592)
Medium	-.1579 (.1789)	.0764781 (.1788)	-.1404 (.1801)	.0375 (.1728)	.1728 (.1791)	-.2335 (.1994)	.1168 (.1861)	-.1723 (.1923)	.0698 (.1871)	.2347 (.1770)
Large	.0085 (.2506)	-.0266 (.2809)	-.0214 (.2488)	-.0013 (.2657)	1.2627*** (.2778)	-.2148 (.2721)	-.1267 (.2744)	-.1880 (.2585)	-.1309 (.2726)	1.1427*** (.2677)
Capital Intensity	.0480 (.0312)	.0347 (.0330)	.0508 (.0347)	.0347 (.0316)	-.0264 (.0356)	.046442 (.0376)	.0295 (.0351)	.0437 (.0395)	.0298 (.0353)	-.0324 (.0343)
Educated Labor Force	.0236 (.0500)	-.0555 (.0626)	.0111 (.0526)	-.0639 (.0571)	-.0576 (.0667)	.0619269 (.0641)	-.0337 (.0658)	.0323 (.0628)	-.0383 (.0646)	-.0577 (.0640)
Training Decision	.5267*** (.1963)	-.0269 (.1652)	.5375*** (.1891)	-.0054 (.1482)	.5997*** (.2095)	.7124*** (.1885)	-.0385 (.1761)	.6500*** (.1745)	-.0035 (.1701)	.5935*** (.1728)
Constant	-1.603*** (.5809)	-1.1488** (.5367)	-1.732*** (.6222)	-1.0876** (.5144)	-1.0495* (.5868)	-1.953*** (.6141)	-1.1598** (.5647)	-1.954*** (.6406)	-1.1247** (.5674)	-1.1825** (.5616)
Observation	373	373	373	373	373	373	373	373	373	373
ISIC-2 digit dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Thailand shows some results different from Cambodia (Table A.4.12). Thai firms do not depend on R&D investment to introduce innovation outcomes but on their networks and human capital. In terms of networking, Thai firms implement technological cooperation and interaction with suppliers and clients through websites to introduce all types of innovation outcomes and subcontracting to introduce product and process innovations. The medium Thai firms tend to implement organizational innovation, while large Thai firms are less likely to introduce product and process innovation. Thai firms with increasing physical capital are less likely to introduce product innovation. In terms of human capital, firms perceiving larger obstacles in the educated labor force tend to introduce process and organizational innovations. Firms adopting staff training tend to introduce all innovation outcomes. This finding suggests that the Thai innovation system is more mature than the Cambodian innovation system since Thai firms use linkage with public institutions, domestic and foreign firms, parent firms, suppliers, and clients to produce innovation outcomes. Thai education and vocational training systems are also better than Cambodia to create new human resources and upgrade the existing ones. However, Thailand seems not to commit its resources to promote Thai firms to invest in R&D, so its level of private R&D expenditures is low (Rattanakhamfu et al., 2018).

Compared with Cambodia, Vietnam also shows different results. Vietnam tends to depend strongly on R&D investment to introduce innovation outcomes. According to Vo et al. (2018), Vietnam has invested in public R&D expenditures to promote private R&D spending. The Vietnamese innovation system is more mature than Cambodia. Its networking variables, including technological cooperation and interaction with suppliers and clients through the website, play an important role in introducing innovation outcomes. The small Vietnamese firms are likely to implement organizational innovation but less likely to implement process innovation, while large Vietnamese firms are less likely to introduce product innovation. Vietnamese education and vocational training systems are also more sophisticated than Cambodia. The perceived obstacle in the educated labor force and staff training variables tends to induce firms to introduce innovation outcomes (Table A.4.12).

4.5.3 Productivity Function

Table 4.4 demonstrates the estimation of the productivity equation. Cambodian firms need complementary factors, such as labor and physical capital, and innovation outcomes to improve labor productivity. When we apply only two predicted values of probability of product and process innovations in the OLS regression of the productivity equation, the result in Column (1) shows that both of them don't have any impact on labor productivity. However, firms that increase their physical capital investment tend to improve their labor productivity by about 9%. This finding is similar to that of Cirera (2016) and Cirera et al. (2016a). Column (2) shows the OLS regression result of three expected values of the probability of innovation outputs on labor productivity. The result shows that product innovation decision significantly impacts labor productivity, increasing it by about 132%.

However, organizational innovation decision has a significantly negative relationship with labor productivity, which is common, especially in developing countries (Lhuillery et al., 2008; Cirera, 2016). Lhuillery et al. (2008) studied the relationship between R&D, innovation, and productivity and compared European countries with Latin American countries. They found that only Brazil shows a significant impact of the probability of organizational innovation on labor productivity. In contrast, developed countries, such as France and Switzerland, still show negative sign or non-significant. However, Cirera (2016) and Cirera et al. (2016a) found that the probability of innovation outcomes has no significant impact on labor productivity for African developing countries. Besides, firms with a large labor force also impact labor productivity by about 16%. When we analyze the regression of the productivity equation using the predicted value of innovation investment intensity, the result shows the significant impact of capital intensity on labor productivity. This finding is not different from the results of Thailand and Vietnam, which show that predicted values of product innovation and capital intensity have a significant impact on labor productivity (table A.4.13).

For the combination of innovation outputs, there is no significant relationship between the variety of combinations and labor productivity. This result may derive from the fact that the introduction of innovation outcomes requires a substantial amount of money. Hence, firms need to choose the most important one as their priority rather than investing them at the same time. Even though it does not show a significant result, we can interpret their signs to show their complementarity. The result shows that product and process innovations complement each other in Cambodia, contrary to Cirera's (2016) finding in Kenya, but similar to Polder et al. (2010) in Sweden. However, product and organizational innovations and process and organizational innovations substitute, which is the same as Cirera's (2016) finding.

According to Ballot et al. (2011), firms with higher R&D expenditure tend to combine product and process innovations in the absence of organizational innovation; however, they treat product and organizational innovations as complementary. In contrast, firms with lower capabilities tend to treat product and process innovations as a substitute in the absence of organizational innovation. It is difficult to know whether Cambodian firms are high R&D performing firms or low capability firms. It may stay somewhere in the middle between them.

Table 4.4 Productivity Function Using GSEM

Variables	Sales per Worker (R&D Intensity) (Bivariate) (1)	Sales per Worker (R&D Intensity) (Trivariate) (2)	Sales per Worker (Innovation Investment Intensity) (Bivariate)(3)	Sales per Worker (Innovation Investment Intensity) (Trivariate)(4)	Sales per Worker (Combination of Innovation Outputs) (5)	Sales per Worker (Combination of Innovation Outputs) (6)
Capital Intensity	.0877** (.0369)	.0675 (.0430)	.0875** (.0371)	.0644 (.0430)	.0877** (.0376)	.0853** (.0379)
Labor	.0223 (.0680)	.1567* (.0798)	.0172 (.0673)	.1599** (.0784)	.0341 (.0670)	.0719 (.0725)
Predicted Product Innovation	.0458 (.4544)	1.3223** (.5607)	.1380 (.4572)	1.4439*** (.5364)	.2553 (.2451)	.1659 (.2538)
Predicted Process Innovation	.0667 (.5243)	-.6033 (.4833)	.1525 (.4584)	-.2424 (.4538)	.1695 (.2173)	.0990 (.2252)
Predicted Organizational Innovation		-2.2736*** (.4363)		-2.2957*** (.4102)		-.6187** (.3244)
Prod*Proc					.2057 (.3613)	.0949 (.3717)
Prod*Org						-.1349 (.3999)
Proc*Org						-.2531 (.4092)
Prod*Proc*Org						.2350 (.5386)
Constant	16.1468*** (.6411)	16.2789*** (.7296)	16.0905*** (.6345)	16.1721*** (.7217)	16.0647*** (.6459)	16.0824*** (.6532)
Observation	373	373	373	373	373	373
ISIC-2 digit dummy	Yes	Yes	Yes	Yes	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses. In column (5), the values of the three combinations of innovation outcomes replace the predicted values of innovation outcomes. In column (6), predicted values of innovation outcomes are replaced by seven combinations of innovation outcomes using non-innovator as a base category.

4.5.4 Sensitivity Analysis

In the innovation output equation, we add variables related to foreign direct investments and international integration, such as foreign-owned firms, importer, exporter, and two-way trader. We also add variables related to demand-pull factors, competitiveness, and technological factors. Using this way as a sensitivity analysis, we can know whether they have an indirect impact on the innovation outcomes or not. Table A.4.2 shows that these variables' effects on R&D investment are reduced since some of these variables indirectly impact the probability of some types of innovation outcomes. As has been shown, these variables seem to have an indirect impact on performing the innovation outcomes. While the effect of foreign ownership on R&D intensity turns from positive to negative sign, the effect of the importer on it has been reduced or shifted to become negative. On the other hand, the impact of demand increasing and the extent of informal competition has been reduced or turned from significant to non-significant. Furthermore, for technological push factors, their effects have been reduced to become less significant or non-significant.

Table A.4.3 shows the direct impact of these variables on the probability of some types of innovation outcomes. Foreign-owned firms tend to introduce product innovation, while importers tend to implement organizational innovation. This finding suggests that even though foreign-owned firms and importers don't significantly impact R&D intensity, they indirectly impact introducing innovation outcomes through predicted values of innovation inputs in the first stage of the CDM model. When competitive pressures from the informal sector and international market have no significant impact on R&D, the former indirectly impact the probability of product and organizational innovations and the latter on introducing product innovation in the innovation output equation. Meanwhile, when the effects of certification and foreign technology license on R&D investment have been reduced, their indirect impacts on implementing organizational innovation have been significant. However, innovation input intensity no longer affects the probability of innovation outcomes except process innovation when we applied R&D intensity to estimate. Finally, in the productivity equation, firms with increasing physical capital and firms with more labor force significantly impact labor productivity (Table A.4.4). Product innovation decision positively impacts labor productivity, but organizational innovation decision negatively impacts it.

4.5.5 Robustness Checks

4.5.5.1 Comparing with the IV Estimation Method

The sequential IV, which was applied in Griffith et al. (2006), has been used to estimate the current structural equation system in order to compare with the result applying GSEM. In this estimation method, predicted values of innovation inputs become endogenous variables of the innovation outputs equation in stage two of the CDM model. Then, predicted values of innovation outputs become endogenous variables in the productivity equation. In the first stage, endogenous variables of the innovation inputs are regressed on various instrument variables. In the second stage, endogenous variables of the innovation outputs are regressed on various instrument variables and predicted value of innovation inputs. Here, the result is slightly different from the one applying GSEM (Table A.4.5, Table A.4.6, Table A.4.7). This difference may derive from the fact that the IV estimates the structural equation system sequentially. Still, GSEM estimates it simultaneously by allowing the error terms of all equations to be correlated with one another. The IV estimation applies limited information maximum likelihood (LIML), in which only the last equation is estimated simultaneously. On the other hand, GSEM uses FIML, in which all equations are estimated simultaneously.

4.5.5.2 Comparing with SEM Estimation Method

The SEM estimation is not so different from GSEM except that we can interpret it by using the percentage of the probability of R&D engagement or the likelihood of introducing innovation outcomes since SEM applies the linear probability model for dichotomous dependent variables. Its result is not so different from GSEM (Table A.4.8, Table A.4.9, Table A.4.10).

4.6 Conclusion

Cambodian NIS is functioning as an emergent innovation system, which is weaker than Thailand and Vietnam, whose innovation systems can be characterized as the maturing innovation systems. This early stage of Cambodian NIS can be explained by the concept of NIS and its evolution. Cambodian NIS is emerging because the business environment problems are still large, R&D activities are limited, management capabilities are simple, and university-industry linkage is weak. It also has a weak linkage between domestic firms and multinational firms and limited international integration of domestic firms into the international markets.

The investment climate is not conducive to firms that want to decide and invest in innovation inputs because firms still face financing constraints and international trade obstacles. Human capital still does not match labor market needs since firms invest substantially in staff training to introduce innovation outcomes. However, telecommunications and government regulations seem to be enhanced and become policy tools to promote R&D investment. The competitive environment is strong in both national and international markets, incentivizing firms to invest in R&D and introduce innovation outcomes. This improved investment climate may explain why firms are willing to expand their operation by increasing labor force and physical capital in addition to introducing product innovation to boost firm productivity.

Firms tend to increase R&D investment depending on whether they have complementary factors, including internationally-recognized certifications, foreign technology licenses, and new tangible assets. These complementary factors are low because Cambodian firms lack financing to accumulate them. This low level of complementary factors can partly explain the low level of R&D activities at only 10% of sample firms.

Cambodian firms show a bit of progress in transforming the innovation inputs into innovation outcomes. However, product innovation decision has only a small impact on labor productivity. This means that Cambodian firms have limited management capabilities. On the other hand, the weak link between firms and other firms or public institutions to introduce product innovation also addresses the basic management capabilities. This low level of management capabilities can partly explain the limited R&D activities.

The interaction between firms and other firms or public institutions is still weak. While technological cooperation and subcontracting represent only 7% and 14% of sample firms, interaction with clients and supplies using website and email represents 27% and 56%. Cambodian firms adopt technological cooperation to develop process innovation and subcontracting to introduce product and organizational innovations. Cambodian firms that interact with clients and suppliers using email and website as the information sources are more likely to introduce product innovation. This limited interaction between firms and public institutions may derive from the limited management capabilities of both parties. Technological cooperation is adopted to introduce both product and process innovations; however, Cambodia applies it to introduce only process innovation, suggesting their low level of management capabilities.

Cambodia has limited integration of its domestic firms into international markets, RVCs, and GVCs. Even though Cambodia has attracted many multinational firms, these firms treat it as the export platform because most export-oriented firms are foreign-owned. In addition, foreign-owned firms and two-way traders represent around 10% and 22% of the sample firms, respectively. On the other hand, Cambodian firms need financing, human capital, R&D activities, management capabilities, low importing and exporting costs, and technological factors to upgrade their firm capabilities to become exporters, innovative local suppliers, and global firms. However, Cambodian firms lack financing and skilled workers, have a low level of R&D activities and management capabilities, and face high trade costs. They also accumulate a small stock of knowledge from external sources such as internationally-recognized certifications, foreign technology licenses, and new machinery and equipment. The lack of these complementary factors makes Cambodian firms have such a low level of firm capabilities that they cannot integrate themselves into international markets and international production networks.

While firm size and importer do not play an essential role in increasing R&D investment, they play a role in producing organizational innovation and the former impacts on labor productivity. Similarly, while foreign-owned firms do not tend to invest in R&D, they show commitment to introduce product innovation in the innovation process. Furthermore, firms with certification and foreign technology licenses also tend to implement organizational innovation. Even though the result does not show a significant impact of any combination of innovation outcomes on labor productivity, their sign can be interpreted that product and process innovations are complementary regardless of the organizational innovation. Product innovation and organizational innovation, as well as process innovation and organizational innovation, substitute each other.

Compared with the neighboring countries, Cambodian NIS is weaker than Thailand and Vietnam, whose innovation systems are fragmented. Thai business environment seems to be more conducive to the innovation activities since it can integrate their firms into international markets and global value chains better than Cambodia. Thai government capabilities have also been improved to support the innovation performance. However, Thailand still lacks financing and has an inconducive competitive environment to support innovation. Thai firms with internationally-recognized certification and the investment in new machinery and equipment tend to invest in R&D. Thailand has a low level of R&D activities, but its firms depend on the interaction with other firms and public research institutions to support their innovation performance. Even though its R&D has no impact on innovation outputs, product innovation has a significant impact on labor productivity. This suggests that Thai firms may have higher management capabilities than Cambodia to offset its low level of R&D to improve labor productivity. Thailand also has better national education and training system than Cambodia to produce a new workforce and upgrade the existing one to support the firm capabilities.

A Vietnamese innovation system is positioned somewhere between Cambodia and Thailand. The domestic competitive pressure tends to promote R&D activities. Like Cambodia, Vietnam has complementary factors such as internationally-recognized certification, foreign technology licenses, and new machinery and equipment to promote R&D investment. It also invests in significant public R&D to encourage SMEs to produce new products and processes to capture both large domestic and foreign markets. Thus, Vietnam has a higher level of R&D than Thailand and Cambodia. It also relies on the interaction with other firms, public research institutions, suppliers, and clients to learn new knowledge and technologies. Even though Vietnamese firms have a higher level of R&D that contributes to introduce innovation outcomes, they have only product innovation decision that significantly impacts labor productivity. This connection suggests that Vietnamese firms have a lower level of management capabilities than Thailand. Vietnamese education and training system is also better than Cambodia but still worse than Thailand in upgrading the existing workforce and new ones to support the Vietnamese firm capabilities.

Cambodia needs to improve the investment climate by strengthening the financial and capital market to support Cambodian firms' access to finance. SME Bank that the government plans to create and operate to provide both traditional and non-traditional financial services for SMEs is the right and suitable measure to help them get financing to invest in more significant physical capital and R&D activities. For example, SME Bank has created SME co-financing services that match the loan with commercial banks or micro-financial institutions with subsidized credit rates to support SMEs. On the other hand, the Guarantee Scheme Corporation of Cambodia (GSCC) that the government has just created should implement at the national level to gain significant development impacts. This scheme helps SMEs with limited collaterals and financial constraints to access finance if they have long-term innovation projects with growth potentials. Another innovative financial service is match-granting. It is used to promote domestic firms in invest in R&D activities by matching the public fund with their actual R&D expenditure.

Cambodia also needs to improve transportation infrastructure and trade regulation to reduce the cost of exporting and importing. Hence, firms have the incentives to invest in innovation inputs such as new machinery and equipment, internationally-recognized certification, foreign technology licenses, and R&D since their investment can increase their profits through international trade. Even though staff training plays an essential role in developing human capital in the firms, it is only a temporary measure to upgrade the skills for only the labor market's current workforce. To upgrade human capital for both new and current workforce, the government should develop the national education and training system to provide high-quality education and training services to develop adequate human capital. The human capital includes technicians, engineers, scientists, and entrepreneurs who can help support the firms to upgrade their capabilities.

The low management and production capabilities require the government to develop the firm capability upgrading system to provide quality consulting services to upgrade it. The presence of multinational firms in Cambodia means that professional trainers with different skills can be the right sources of knowledge. Cambodia can attract them to join the training and advanced consulting services by using an appropriate incentive system. When management and production capabilities are upgraded for the critical mass of firms, those firms may recognize technological opportunities and tend to invest in long-term innovation projects. To implement them successfully, they need to develop human resource policies to cultivate qualified human resources (Cirera et al., 2017). Then, the demand for R&D activities conducted by the public sector will increase, and firms may need substantial support from universities and public R&D institutes by applying the public-private collaboration projects. Cambodian NIS can be upgraded to become a mature NIS through these collaboration projects, helping Cambodia catch up with the technological frontier economies.

Chapter 5: Transformation of Competitive Advantage - Analysis of Trade Specialization of Cambodian Industries

5.1 Introduction

Cambodia has the vision to transform and modernize its labor-intensive industries to become skill-based industries by 2025 (RGC, 2015). This long-term goal can be achieved by improving the local industries' productivity to strengthen their competitiveness and by linking them to the regional production networks and global value chains to develop modern technology-based sectors by 2025. Through the vision achievement, Cambodia can create more quality jobs, increase income for its citizens, move up the value chains in the regional and global production networks, and obtain further sustainable and inclusive economic development. Three phases have been introduced to conduct the structural change of the industries. Firstly, new labor-intensive sectors such as manufacturing and agro-industry need to be more diversified by attracting domestic and foreign direct investments in those industries. Secondly, industrial restructuring should be pursued to enlarge the production base in non-traditional industries by modernizing and improving the productivity of new industries. Finally, the specialization of potential new sectors should have been promoted through upgrading science, technology, and innovation system to diversify the economic activities into non-traditional sectors in Cambodia.

As a consequence, Cambodia has accelerated the economically structural transformation in 2016. Agriculture's contribution to the GDP declined to 26.3% in 2016, down from 31.6% in 2013. Whereas industries, higher value-added manufacturers, increase GDP contribution up to 31.3%, from only 24.1% in 2013. The service sector stayed nearly the same at 42.4%. In the industrial sector, the garment sector's export growth moderated at 5.4% year-on-year basis in mid-2017, down from 8.4% (y/y) at the end of 2016; meanwhile, the emerging manufacturing sector increased substantially up to 16% of GDP by 2016. The emerging industries include electronic appliance parts, earphones, automobile parts, wire harnesses, electrical parts, optical parts, metal building materials, construction materials, and connectors (World Bank, 2017c). Cambodia needs to further structural transformation and promote trade and technological specialization in new industries. However, there is little study focusing on the analysis of the pattern of trade specialization at the national and industry level. Therefore, it is necessary to understand it to develop the sectoral innovation policies to support the transformation.

Chapter 5 aims to analyze trade specialization pattern at the national and industry levels. Cambodia's science and technology system is still incipient. Cambodia is experiencing industrial transformation with a little technological change to support its transformation. It reveals trade specialization in 15 growing (four high-tech and 11 low-tech), 28 emerging (16 high-tech and 12 low-tech), and 84 marginal industries (11 high-tech and 73 low-tech). In general, Cambodia has a concentration pattern of trade specialization on a few traditional industries. Cambodia shows the elements of stickiness and incremental change in low-tech and high-tech industries, in which the initial values of trade specialization move slowly toward the average within sectors. Also, there is mobility between sectors toward the broad pattern of trade specialization. Cambodia experiences a slight diversification of trade specialization in the long period, but it has started to concentrate its industries with a slow movement in the last two periods.

This chapter is constructed as follows. Section 5.2 focuses on the theoretical framework and the empirical evidence as a basis for analyzing the patterns of trade specialization at the national and industry levels. In section 5.3, data and research methodology will be reviewed to adopt the appropriate research methodology for analyzing the data for answering the above research purposes. Results will be shown and explained in section 5.4, and section 5.5 concludes.

5.2 Conceptual framework and the empirical evidence

As the economic theory of technological change and international trade is complex, I will start the literature review with a simple concept and move to the more complex ones.

Technology is not just the information or the set of blueprints. Still, it is the form of specific knowledge that yields the ordered cumulative and irreversible technical change to create the technological paradigm, which is country-specific (Dosi et al., 1988). In a country, there are mixes of different techniques, products, and firms that co-exist with one another at a point in time. According to the technical change mechanism, these techniques, products, and firms have been selected in the Schumpeterian competition as the evolutionary processes of innovation and diffusion, applying the concept of learning by doing. As a result, better techniques, products, and firms can survive while the bad ones exit from the markets.

Since the concept of learning by doing has been recognized to play an essential role in explaining the evolution of the industrial structure, Anderson (2010) clearly explained it based on the evolutionary foundations of the Nelson and Winter model. In a given industry, many firms are producing differentiated goods with similar characteristics. These firms apply the existing productive routines to make the total productivity growth. In this sense, they keep implementing these current productive routines until they find a new routine. However, firms begin a new search only when their profitability falls under a certain threshold. This fall in profitability derives from their production processes' problems or their product characteristics' weaknesses. These specific problems encourage them to start a new search to find the “favorable responses.” In this innovation process, firms rationally start a “localized” search because its success rate is high. However, this search and the implementation of its results are still costly and uncertain. With this behavior, firms mostly perform permanent and production-near search and learning; however, this alternative view only represents the localized character of the activity. In this way, firms only obtain small productivity gains and cannot significantly jump in their production performance.

In contrast, with entirely new productive routines, firms can build their competitiveness in their selection environment. They can increase their profitability and have the possibility to improve their production capability and market share. In the evolutionary path of firms located in a given industry, firms need to learn from the available global knowledge and rely on localized learning, innovation, and knowledge diffusion. We define “localized” as an activity that is country- or industry-specific. So, localized search represents the particular characteristics of the national pattern of specialization. In this sense, we refer to the lock-in of national firms or industries as the asset specificity and the difficulty of entering into the well-established sectors due to a large amount of tacit knowledge. Firms need to find favorable responses based on their existing skills and technological expertise as well as through cooperation with other firms with higher technological and organizational capabilities or with universities and R&D institutes to cope with the mentioned problems.

Unger (1988) provide a good example as empirical evidence for explaining the lack of entirely new productive routines among firms that make developing countries cannot gain higher productivity growth. He stated that Less Developed Countries (LDC) previously adopted and implemented the import substitution industrialization strategies. They have developed the final consumer industries in the oligopolistic markets, relying on imported technology and a few incentives or rewards for entrepreneurial risk-taking. However, when they apply new industrial policies such as export promotion strategies or technological leapfrogging strategies, they are rarely successful. This problem may be due to the fact that they don’t have the necessary Schumpeterian entrepreneurs to develop the local supply industries to support the final consumer industries.

When two industries are included in the analysis, one industry may reveal a higher productivity increase than the other, even though they experience the same growth rate. This sectoral difference in productivity increase derives from the different distribution of the world income among the two industries. According to Anderson (2010), the development block shows the connection of the historically recorded innovations between inter-related sectors and the entrepreneurs' expectations of innovative products' potentials.

Anderson (2010) used the term "development block" but combined the structural and evolutionary approaches to explain it. Development block is the combination of various interrelated sectors. It can create core innovation in the system, introducing structural tensions and partial resolutions. This core innovation can directly or indirectly induce the related innovations representing new niches, filled by chances or by innovative jumps. He proposed that the development block that is immature and well-established in the national economy can promote international competitiveness and development power.

Like the concept of development block, Fagerberg (2003) introduced the Mark-Schumpeter model of technological competition, explaining the regularities of the innovation-diffusion process. In the Mark-Schumpeter model of technological competition, innovation-diffusion is a creative process. A firm that launches an innovative product may induce other firms in the same sector to imitate the core of innovation in producing their differentiated products. As a result, the industry grows significantly for a while. Then, the imitators can become successful only if they improve the original innovation and become innovators. Later, the sector's growth slows down since the effect of innovation on growth has decreased. In most sectors, regularities occur when original innovations induce the imitators to create innovations in similar or related sectors due to the interdependencies between the original innovations and induced innovations.

Vernon (1966) developed the product-life-cycle theory to explain how new technologies are diffused from developed to developing countries. When a vital product innovation induces innovations in similar or related sectors to compete in the market, it is called the product-life-cycle concept. It is composed of four stages, such as introduction, growth, maturity, and declining phases. The original innovation's profit incentives have induced many firms to produce many products related to the original innovation at the early stage. When the induced innovations significantly increase during the growth and maturity periods, then they become standardized. This standardization may accompany the process innovation, the economy of scale, and the cost competition and promotes technology transfer from innovator countries (developed countries) to developing countries through foreign direct investments.

However, the industrial structure is not developed at the product level but at the sectoral level, which follows the specific technology trajectories. Thus, the technology life cycle concept should be applied rather than the product life cycle to analyze the particular technology trajectories to understand the windows of opportunities for the latecomer countries to catch up with the frontier ones. There are four stages in the technology life cycle: introduction, early growth, late growth, and maturity (Perez et al., 1988). When firms enter a new technological system at the introduction stage, they require a low level of investment capital and a low level of experience, management, and marketing skills. However, they need an adequate accumulated stock of technological knowledge and a high locational advantage. On the other hand, entering the maturity stage requires higher investment costs and a higher level of experience and skills but lower technological knowledge and locational advantage levels. For the early growth and late growth stages, firms need higher investment costs and a higher level of experience and skills. At the same time, they have already accumulated adequate technological knowledge and have invested substantially in the distribution infrastructure.

Like the development block concept, Dosi et al. (1990) suggested the cluster concept to explain the technological accumulation pattern. The cluster is traditionally defined as the inter-linkages represented by input requirements, prices, and commodity flows. It can be summarized as the structured sub-sets of activities related to the demand side of those activities. However, Dosi et al. (1990) viewed cluster as the structured sub-sets of technological and informational externalities, which can impact developing a group of industries. They recognized that a country that shows traditional production capabilities in electronics would have the ability to learn and exploit new technologies related to the existing industries through cumulative processes. For instance, with the well-established chemical industries, Switzerland can successfully develop the biotechnology industries through cumulative processes of interrelated sectors.

Dosi et al. (1990) studied the determinants of the pattern of technological accumulation. The determinants include the economic stimuli, industrial cluster, and structure and dynamics of the home markets. The economic stimuli include the pressure to substitute labor for machines and the abundance or scarcity of economic inputs, which are not the only factor to help pull the country's technological accumulation. The industrial cluster can also help support it by allowing firms to access the information flows, learning processes, and technological complementarities. The home market's structure and dynamics represent the consumption goods and intermediate inputs markets, which are also important to support it.

This model suggests the government to intervene in upgrading the innovativeness, inputs efficiencies, and organizational and technological capabilities of domestic firms to promote the structural transformation and economic catching up. These public interventions can fill up the missing middle of the neo-classical economic approach's micro-foundations and Keynesian approach's macroeconomic activity level. Lee et al. (2018) proposed a model to help latecomer countries catch up with the frontier ones. To sustain catching-up, latecomer firms need to enhance their firm capabilities and find the market niches and shift from endowment-based to technology-based specializations. If they don't apply this leapfrogging strategy, they may fall into the upper-middle-income trap when latecomers become more developed. For this trap, their wage rates cannot compete with lower-wage manufacturers in low-income countries. At the same time, their innovation capabilities cannot compete with higher-wage innovators in high-income countries. Successive industrial leadership changes from incumbents to latecomers. This phenomenon depends on the diverse windows of opportunities together with incumbents and latecomers' responses under the support of their sectoral and national innovation systems.

World Bank (2010) suggested several ways to develop competitive industries in developing countries since developing them is the source of wealth and pride. First, the government should adopt both direct and indirect public support to make innovative initiatives germinate and grow in the innovation system. The innovation processes work not only with direct support but also with indirect interventions at the necessary level. Particularly, all the efficient value chains in the specific industries should be properly functioning and delivered in a holistic approach to make the innovation processes work successfully. Second, it should also afford an adequate infrastructure and a friendly business climate to support innovation-related activities. It can raise the technological and knowledge level for developing competitive and innovative industries by providing the firms with appropriate technical services and encouraging cooperation among universities, research centers, financial institutions, and firms. Finally, the higher-ranking government leaders should engage with a clear strategic vision in the innovation policy to attract the essential foreign direct investments and mobilize the critical mass of private firms to develop the priority competitive industries. Policymakers should remove the obstacles and initiate the innovative project pilots as micro-reforms to move up to the national level structural reform later.

Several studies show and explain the stability of trade specialization pattern, which are evidence of the model of trade and technology. Dalum et al. (1996) studied the stability pattern of export specialization in 20 OECD countries by analyzing the intra-country across industries and intra-industry across countries. For the analysis of intra-country inter-sectoral differences, the result shows the elements of stickiness and incremental change for the trade specialization pattern within those countries. This finding means that the initial less specialized industries become more specialized to the average level. In the meanwhile, the initial high specialized industries become less specialized to the average level within industries.

The result that displays σ de-specialization pattern means that industries' proportional position moves to the broader specialization pattern within OECD countries. For the analysis of intra-sectoral inter-national differences, the result indicates the pattern of convergence for both β-convergence and σ-convergence patterns. The former means that countries with the initial less specialized industries tend to converge to the average. Simultaneously, countries with the initial high specialized industries move back to the average within industries. The latter means that there is mobility between industries toward the broad specialization pattern across OECD countries. When the mobility between industries within countries is compared with that across countries, the former's mobility effect is smaller than the latter for 7 percent. This finding suggests that industries tend to converge faster across OECD countries than within them.

Archibugi et al. (1992, 1994) found the convergence in aggregate data in R&D intensity (R&D as a percentage of GDP), in patenting intensity (external patenting per US$ of exports), and in bibliometric indicators (number of the published articles and citations). However, they found some concentration patterns of technological specialization in the disaggregated data.

5.3 Data and Research Methodology

To understand the changes in trade specialization patterns, we calculate the indices of trade specialization using the trade data from the international trade center's website: www.intracen.org. Since this trade data uses a Harmonized System to code their industrial categories, which are different from Standard International Trade Classification (SITC version 3), we need to develop a concordance table based on the conversion table applied in the UN Comtrade. This chapter uses the product classification by technological categories developed by Lall (2000) to construct the concordance table. According to this concordance table, we can construct net trade specialization indices on 90 high-tech industries and 163 low-tech industries for Cambodia. We also apply the same calculation for Thailand and Vietnam.

Then we do the regression on these indices to understand the pattern of trade specialization at the national and industry levels.

In this chapter, we apply the research methodology developed by Dalum et al. (1996). For testing the stability pattern of trade specialization, the Balassa measure may result in a normality distribution problem since the index's value ranges from zero to infinity, and the (weighted) average equal to one. Balassa (1965) applied the logarithmic transformation for the index; however, this method still has a disadvantage because it results in a tremendous negative value. Laursen et al. (1995) coped with the logarithmic transformation's disadvantage by developing a new measure called "reveal symmetric comparative advantage" to resolve the normality problem. Instead of using RCA, we use the net trade specialization index (NTS) proposed by Iapadre (2011). He thought that NTS is a better measurement than the former indicator to analyze the trade specialization patterns since NTS includes import and export data to calculate the indices. NTS also can solve the normality problem, which happens to the Balassa measure.

$$NTS_{i,j} = \frac{\frac{X_{i,j}}{X_{i,q}} - \frac{M_{i,j}}{M_{i,q}}}{\frac{X_{i,j}}{X_{i,q}} + \frac{M_{i,j}}{M_{i,q}}}$$

X and M are the amount of export and import, respectively. i and j represent countries and sectors. Besides, q represents the sum of sectors. In this formula, the value of $NTS_{i,j}$ is between -1 and +1.

We use the bivariate Galtonian regression on the two following equations to analyze the distribution of trade specialization (Dalum et al., 1996).

$$NTS_{ij}^{t} = \alpha + \beta NTS_{ij}^{tn} + e_{ij}^{t}$$

Where i stands for countries, and j stands for product groups. High technology industries, such as high and medium technology industries, have 90 product subgroups with a three-digit level of SITC version 3. Low technology industries have 163 product subgroups with a three-digit level of SITC version 3. They include low technology products, resource-based manufactures, and primary products.

These indices have been divided into four periods: period I (2001-2005), period II (2006-2010), period III (2011-2015), and period IV (2016-2019). t represents period IV, while tn represents previous periods III, II, and I.

If β=1, the specialization pattern is constant. When β>1, the existing pattern of specialization has been strengthened. This condition means that competitive industries become more specialized while the less competitive industries become even less specialized. When 0< β<1, the existing pattern of specialization is represented by the elements of stickiness and incremental change. It means the initial value of NTS move slowly to the average within the sectors. So, the highly competitive industries are not so different from the less competitive ones. On the contrary, when $\beta < 0$, the NTS that initially is above the average becomes the above average one in the final period while the initial below-average one becomes the above-average one in the final period. When the regression effect (1- β) is low (high β), the specialization pattern is concentrated in a few industries. On the contrary, when the regression effect (1- β) is high (low β), it is more diversified.

We use the variance β/ρ to measure the degree of specialization, which is the extent of dispersing trade specialization distribution. ρ is the correlation coefficient. Regarding Hart (1976), with the formula: $\rho = 1 - \frac{\sigma_\varepsilon^2}{\sigma_t^2}$, we have: $\frac{\sigma_i^{2t}}{\sigma_i^{2nt}} = \frac{\beta^2}{\rho^2}\ or\ \frac{\sigma_i^t}{\sigma_i^{nt}} = \frac{|\beta|}{|\rho|}$. When the coefficient β is larger than the correlation coefficient ρ ($\beta/\rho > 1$), the degree of specialization has increased, which is equivalent to the increase in dispersion. When $\beta < \rho$ or $\beta/\rho < 1$, the degree of specialization has decreased, which is equivalent to the decrease in dispersion. When $\beta = \rho$, it has not changed. Coefficient $\beta < 1$ represents the change from the initial value of specialization toward the average within sectors. If this change is outweighed by the mobility effect ($\beta > \rho$), it represents the significant change of proportional position between sectors toward the specialized sectors. In contrast, if the change is not outweighed by the mobility effect ($\beta < \rho$), it represents the slow mobility between sectors toward the broad pattern of specialization.

The Pearson correlation coefficient ρ represents the movement between sectors along the NTS distribution. When the mobility effect (1 - ρ) is low (high ρ), the industries' relative position moves slowly between sectors. However, when the mobility effect (1 - ρ) is high (low ρ), their relative position has changed significantly. This significant change represents the movement of some industries toward one another, while some industries move away from one another. Industries characterized as strong concentration (weak or negative regression effect) and stability (weak mobility effect) represent a strong concentration in a few established industries. On the other hand, industries characterized as more diversification (high regression effect) and significant change (high mobility effect) represent the significant change of specialization pattern.

5.4 Results

5.4.1 Analysis of Pattern of Trade Specialization at the Aggregate Industrial Level

Table 5.4.1 shows the trade specialization pattern of five major product groups for the four consecutive periods for Cambodia, Thailand, and Vietnam. In Cambodia, product groups in high and medium technologies have lost the trade specialization for all the periods, while product groups in low technology gain the trade specialization for all the periods. When product groups are divided into further subgroups, Cambodia has its electronics industries achieve significant trade specialization in the last two periods. At the meanwhile, other HT product and MT product subgroups lose their trade specialization for all periods. However, the latter shows the improvement of NTS in general, particularly significant are in the automotive and engineering industries. In LT industries, product subgroups in the textile, garment, and footwear gain significant NTS for all the periods but slightly decelerate. Even though the product subgroup in other LT manufactures shows negative NTS, their NTS has improved significantly from the first period to the last period. Besides, while both product subgroups in RB manufactures show negative NTS, they offer significant NTS improvement. The primary product group still loses its net NTS, even though it gains significantly for the third period.

According to this figure, Cambodia is in the early industrial transformation process into electronics, automotive, engineering, and low-tech industries other than garments, such as other LT and resource-based manufactures. However, it still depends substantially on the garment and agriculture sectors.

In comparison, Thailand has its electronics industry gain NTS during all the periods, while its other HT loses trade specialization and is stagnant, resulting in a small loss of NTS in HT industries in the last period. Thailand shows small positive trade specialization in the MT industries for the last three periods. This improvement derives from the significantly positive trade specialization in automotive sectors accompanied by the process and engineering sectors' progress though from a low base. Thailand is diversifying its economy away from LT industries since their NTS has decreased substantially. When considering even further subgroups, Thailand still offers positive NTS in garment products but significantly decelerates, and other LT deteriorates. However, it is gaining trade specialization in RB manufactures, particularly in agro-based products. In primary products, Thailand experiences a significant loss in trade specialization for all periods. Thailand diversifies its economic structure into HT and MT industries, particularly in electronics, automotive, and engineering industries, while moving away from the garment, other LT, and agriculture sectors. However, it still relies on the garment and resource-based manufactures, with a more considerable degree to the latter.

Vietnam is increasing its trade specialization in HT industries from a low base to a small positive one in the last period. This improvement emerges from the progress of both electronics and other HT, particularly in electronics. For MT industries, Vietnam shows a significant loss of trade specialization. However, their NTS has been improved significantly over time, particularly in the automotive and engineering industries. In LT manufactures, Cambodia shows a similar positive result to Vietnam, but the latter makes much progress in other LT industries. In RB manufactures, Vietnam shows a similar pattern to Cambodia, but its trade specialization is larger than the latter. In primary products, Vietnam has been decelerating its trade specialization and reveals positive NTS for only the first three periods. Vietnam diversifies its economic structure into electronics, other HT products, automotive, engineering, other LT, and resource-based sectors. However, Vietnam still depends on LT manufactures and agriculture.

Table 5.4.1 NTS Indices at the Aggregate Industry Level

Product groups	I	II	III	IV	I	II	III	IV	I	II	III	IV
	Cambodia				Thailand				Vietnam			
HT	-0.93	-0.94	-0.68	-0.35	0.05	0.07	0.01	-0.02	-0.36	-0.15	-0.02	0.02
Electronics	-0.78	-0.64	0.38	0.65	0.10	0.11	0.07	0.03	-0.12	-0.07	0.02	0.04
Other HT	-0.93	-0.91	-0.92	-0.90	-0.38	-0.33	-0.45	-0.38	-0.90	-0.66	-0.43	-0.26
MT	-0.93	-0.78	-0.73	-0.68	-0.07	0.03	0.06	0.10	-0.76	-0.56	-0.44	-0.39
Automotive	-0.92	-0.62	-0.36	-0.50	0.24	0.45	0.43	0.48	-0.65	-0.49	-0.27	-0.35
Process	-0.96	-0.96	-0.95	-0.91	-0.22	-0.15	-0.04	-0.09	-0.86	-0.75	-0.65	-0.67
Engineering	-0.85	-0.71	-0.81	-0.63	-0.08	-0.04	-0.05	0.01	-0.69	-0.43	-0.31	-0.25
LT	0.43	0.39	0.34	0.35	0.15	-0.02	-0.08	-0.14	0.30	0.35	0.34	0.39
Garment	0.54	0.48	0.43	0.46	0.54	0.38	0.26	0.11	0.50	0.55	0.55	0.59
Other LT	-0.90	-0.81	-0.74	-0.53	-0.08	-0.16	-0.19	-0.22	-0.19	0.04	-0.02	0.04
RB	-0.89	-0.88	-0.78	-0.73	0.22	0.31	0.39	0.33	-0.48	-0.48	-0.31	-0.27
Agro-based	-0.81	-0.77	-0.64	-0.70	0.46	0.51	0.51	0.49	-0.16	-0.18	-0.15	-0.08
Other	-0.99	-0.97	-0.93	-0.77	-0.04	0.12	0.27	0.12	-0.67	-0.62	-0.42	-0.42
Primary Products	-0.05	-0.12	0.11	-0.18	-0.26	-0.38	-0.41	-0.39	0.66	0.53	0.29	-0.05

Note: HT: High technology manufactures, MT: Medium technology manufactures, LT: Low technology manufactures, RB: Resource-based Manufacture

Source: International Trade Center, 2020

5.4.2 Analysis of Pattern of Trade Specialization at the National Level

Tables 5.4.2 shows the result of the Galtonian regression analysis of the NTS for both low-tech and high-tech industries for Cambodia, Thailand, and Vietnam. In general, Cambodian sectors show the concentration pattern in a few established ones. The high-tech and low-tech industries seem to reflect the concentration of specialization in the established industries in more recent periods because the regression effect and mobility effect's values become lower. However, in the long period IV-I, Cambodia shows a slight diversification of specialization but with a weak mobility effect.

Cambodian industries show cumulative trade specialization in all periods since the coefficient $\hat{\beta}$ show statistical significance at p-value=0.01. The value of $\hat{\beta}$ is significantly less than one shows that Cambodia’s existing pattern of specialization has changed incrementally. The sectors with the initial low value of trade specialization move slowly to the average, while industries with the initial high value of trade specialization move back to the average within sectors. The value of the degree of trade specialization is less than one shows that Cambodia's specialization pattern has decreased due to the decline in the dispersion of the trade specialization distribution. Still, this dispersion increases over time since its degree of specialization increases. Cambodian industries tend to move slowly, but more quickly over a long period, between sectors toward the sectors with a broad pattern of trade specialization.

Table 5.4.2 NTS Indices of Industries

Period	$\hat{\beta}$	Degree of Specialization	Regression Effect	Mobility Effect
Cambodia				
IV-I	.3707*** (.0538)	0.3721	0.6292	0.0037
IV-II	.5857*** (.0555)	0.5880	0.4143	0.0039
IV-III	.7773*** (.0414)	0.7790	0.2227	0.0022
Thailand				
IV-I	.6304*** (.0393)	0.6319	0.3695	0.0023
IV-II	.7725*** (.0335)	0.7738	0.2275	0.0017
IV-III	.9012*** (.0261)	0.9022	0.0988	0.0010
Vietnam				
IV-I	.5177*** (.0483)	0.5193	0.4823	0.0030
IV-II	.7486*** (.0391)	0.7501	0.2514	0.0020
IV-III	.8456*** (.0303)	0.8467	0.1543	0.0012

Note: Period I = 2001-2005, Period II = 2006-2010, Period III = 2011-2015, Period IV = 2016-2019

*, **, *** = statistically significant at the 0.10, 0.05, and 0.01 level, respectively: H_0: $\beta=1$

The degree of specialization = $\hat{\beta}/\hat{\rho}$, the regression effect = $(1-\hat{\beta})$, the mobility effect = $(1-\hat{\rho})$

Source: International Trade Center, 2020

Cambodia has a similar pattern to Thailand and Vietnam, but its degree is smaller than the latter. In general, they have a stronger concentration pattern only on a few established industries than Cambodia. Thailand and Vietnam also reveal stickiness and incremental change within and between sectors to a larger extent than Cambodia. This phenomenon means that their trade specialization indices' initial values move more quickly to the average within industries than Cambodia. There is quicker mobility between sectors toward the broad pattern of trade specialization than in Cambodia. The degree of specialization of both neighboring countries is larger than in Cambodia, suggesting that their mobility speed between sectors is faster toward the broad pattern than in Cambodia.

The slow movement within and between sectors found above shows the characteristics of learning by doing explained by Andersen (2010). He uses the evolutionary foundation of Nelson and Winter to explain it. When firms in a given industry counter-face the specific problems such as the production process's problems and the product characteristics' weaknesses, they tend to earn just small productivity gains and low profitability. As a result, they rationally start a localized search to find the favorable responses. However, this production-near search and learning are difficult for firms to jump in production performance to reach higher profitability and higher productivity gains. This concept of learning by doing can help explain the stability of trade specialization of the industries in Cambodia, Thailand, and Vietnam.

Andersen (2010) also demonstrated that firms with entirely new productive routines tend to jump in their production performance and earns high productivity gains in the selection environment. The entirely new productive routines may be obtained by conducting R&D activities inside the firms or interacting with other firms with a good stock of technological capabilities or with R&D institutes to learn new knowledge and technologies. According to Andersen (2010), the finding that shows slow mobility within and between sectors implies that Cambodia lacks the science and technology system to support trade specialization in high-tech and low-tech industries during the last two periods. Such a low level of support makes Cambodia have a small number of medium-sized exporters in the economic structure.

According to Unger (1988), like Cambodia, Less Developed Countries (LDC) need a critical mass of Schumpeterian entrepreneurs who can learn and adapt the technological and organizational innovations into the local context than ever to cope with the international dynamics of competition. The standard diffusion model mistakenly assumes that the profit incentives will promote the firms to learn new knowledge and technologies, and the supply of entrepreneurs will automatically increase. However, the latter assumption is not valid in LDC like Cambodia. The entrepreneurial factor is as scarce as other economic factors.

This conclusion is similar to UNDP's (2013) finding, which concludes that Cambodia has a small number of entrepreneurs with adequate organizational and technological capabilities. This less representation of entrepreneurs may derive from the fact that the return of natural resources investment is higher than the return of the investment in productive industries and the low level of the supporting institutions to help upgrade the organizational and technological capabilities among Cambodian firms.

Unger (1988) proposed that the development of the capital goods sector and its qualification is essential to accumulate the technological and organizational capabilities to support the industrial development strategies in LDCs. According to this discussion, Cambodia needs to develop a national science and technology system to mobilize the critical mass of domestic firms and upgrade their organizational and technological capabilities. Therefore, they can contribute to the structural transformation of Cambodia.

5.4.3 Analysis of the Pattern of Trade Specialization at the Industry Level

Figure 5.4.3 shows the changes in trade specialization for both periods: 2001-2005 and 2016-2019. The industries located in the upper right quadrant represent cumulative trade specialization. While industries in the lower right quadrant have lost trade specialization, those in the upper left quadrant have gained it. For industries in the lower left quadrant, they have negative trade specialization in both periods.

Cambodia is earning foreign exchange from 15 growing industries in low-tech ones, including nine garment, footwear, and travel goods, four primary products, one agro-based product, and one other resource-based product (Table A.5.1). Cambodia also gains trade specialization in 12 emerging low-tech industries in the last period. The emerging sectors include five primary products, two agro-based products, two other resource-based manufactures, and two non-garment products. Those industries include crustacean, rice, vegetables, vegetable oils, sugar, cocoa, Parts and furniture, Concentrates and ores of precious metal, and Baby carriage, toys, games, and sporting goods. Cambodia experiences a loss in trade specialization in 11 low-tech industries. However, among these lost industries, two industries still have indices of NTS larger than -0.5.

Besides, 71 marginal low-tech industries have their NTS indices increasing (table A.5.1). Among those marginal industries, there are 54 industries, which is not in the garment sector. They also have 11 sectors with NTS between -0.5 and 0. Those industries include three primary, four resource-based, two garment, and two non-garment products. If compared with neighboring countries, Cambodia is still weaker in terms of low-tech industries. Thailand has 60 growing low-tech, 18 emerging low-tech, 18 marginal, and 12 losing low-tech industries. Vietnam has 30 growing low-tech, 29 emerging low-tech, 94 marginal, and 15 losing low-tech industries.

According to Lall (2000), Cambodian low-technology products show stable and well-diffused technologies because technologies are embodied in the capital equipment. They are the kinds of undifferentiated products based on price competition, so low labor cost plays a critical role in gaining competitiveness. Garment industries in Cambodia are developed by FDIs focusing on the low end of the product line, even though they start to diversify into high-end products in recent years (World Bank, 2017c). This phenomenon also happens to low-tech products other than garment. Cambodia also has gained trade specialization in many resource-based products other than agro-based, which show its particular competitiveness.

The high-tech industries are classified into HT in electronics, other HT, MT in automotive, MT in process, and MT in engineering (Lall, 2000). In Cambodian high-tech industries (Figure 5.4.3), there are five emerging industries in electronics, including Automatic data processing machines (752), Parts and accessories for machines (759), Electric power machinery and parts (771), Rotating electric plant and parts (716), and Cathode valves and tubes (776). They also include two marginal high-tech industries other than electronics, such as Medicinal and pharmaceutical products (541) and Electrical machinery & apparatus (778). However, there are three losing high-tech industries, including Aircraft and associated equipment (792), Measuring, analyzing, and controlling apparatus (874), and Telecommunication equipment and parts (764). These two product subgroups should also be restored since developing them can help promote further industrialization.

Cambodia appears a less dominant feature in high-tech sectors than neighboring countries. Thailand has NTS in a greater number of high-tech industries, including five growing high-tech (three in electronics, two in other HT), two emerging electronics, seven marginal high-tech (five in electronics, two in other HT), and two losing electronics industries. Vietnam operates in many more high-tech industries, such as six growing high-tech (five in electronics, one in other HT), four emerging high-tech (two in electronics, two in other HT), seven marginal high-tech (four in electronics, three in other HT), and two losing industries (one in electronics, and one in other HT).

According to Lall (2000), Cambodian electronics industries can be characterized as the labor-intensive final assembly because their high value-to-weight ratio helps induce multinational firms to locate them in a low-wage country like Cambodia. However, the most advanced technology industries in electronics and other HT products require adequate national technological infrastructure and specialized skills to support them. Remarkably, they need interaction between firms and between firms and universities or technological centers to learn new knowledge and technologies and adapt them into the local context before diffusing them in the whole economy. In this sense, Cambodia needs to upgrade its national science and technology system to resolve these systematic problems.

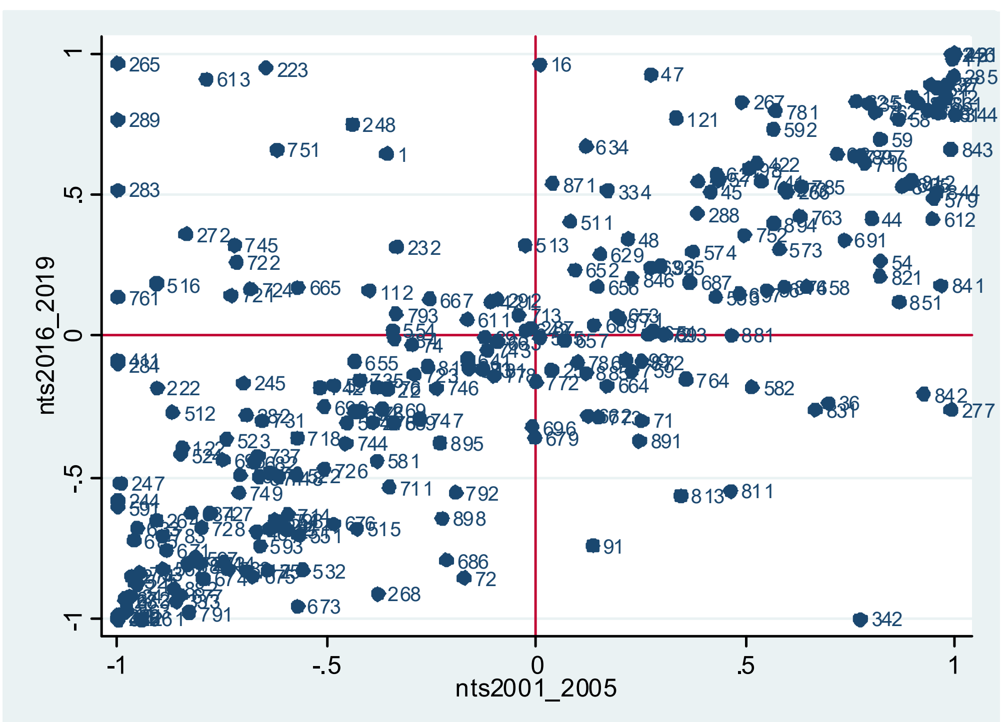
Cambodian medium-tech industries include four growing, 12 emerging, and eight marginal industries. The four growing industries include one automotive, one process, and two engineering sectors. Among the 12 emerging industries, there are one automotive, five process, and six engineering sectors. The eight marginal industries include six process and two engineering ones. However, there are 20 losing medium-tech products (two in automotive, four in process, and 14 in engineering products).

Cambodia shows weaker trade specialization in terms of medium-tech products if compared with the neighboring countries. Thailand operates in many more medium-tech industries, including 19 growing medium-tech (four in automotive, nine in process, and six in engineering) and eight emerging medium-tech (two in process and six in engineering). They also include 33 marginal medium-tech (two in automotive, 11 in process, 20 in engineering) and seven losing medium-tech industries (three in process and four in engineering). Vietnam experiences eight growing medium-tech (one in automotive, three in process, and four in engineering products) and seven emerging medium-tech (one in process and six in engineering products). They also include 25 marginal medium-tech (one in automotive, 10 in process, and 14 in engineering products), and 12 losing medium-tech industries (one in automotive, five in process, and six in engineering products).

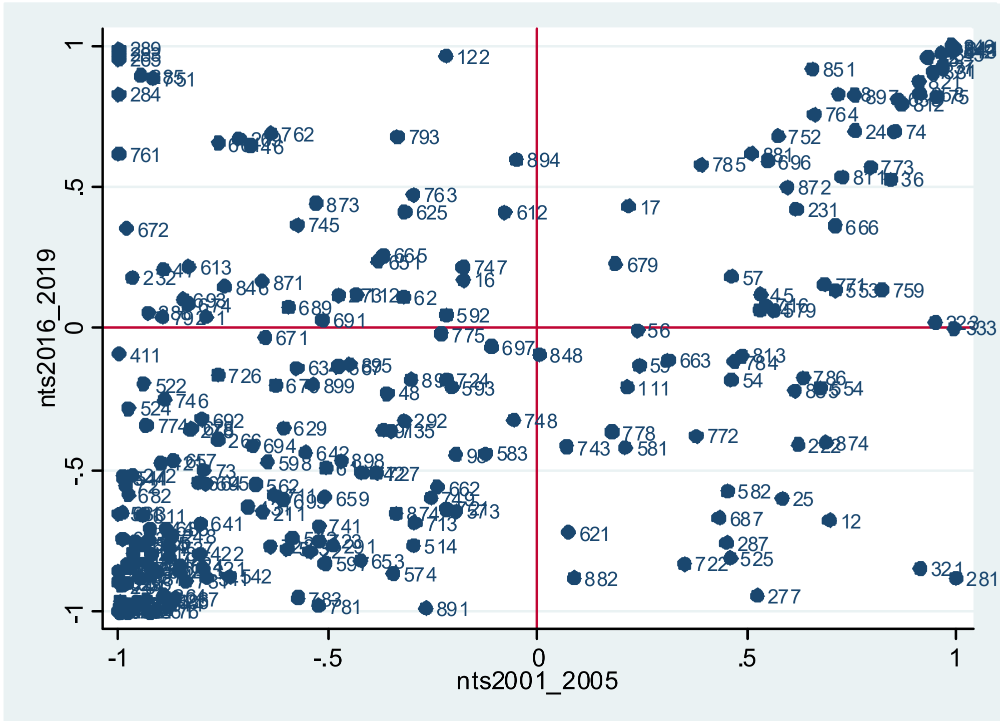
Figure 5.4.3 Changes in NTS Indices

Cambodia

Thailand



Vietnam



Note: Growing industries: NTS > 0 in both periods. Emerging industries: NTS < 0 in 2001-2005 and NTS > 0 in 2016-2019. Losing Industries: NTS > 0 in 2001-2005 and NTS < 0 in 2016-2019. Marginal Industries: NTS < 0 in both periods but increasing

Source: International Trade Center, 2020

Even though the relocation of these MT industries' labor-intensive processes is not widespread in the low-wage areas, it happens in Cambodia. According to Lall (2000), medium-tech products tend to have high technology complexities, which need adequate R&D activities, high-skilled labor force, and long-period learning. The development of the automotive and engineering industries requires the linkage-intensive scale between firms and between firms and universities or R&D institutes to develop their products or processes to reach the international standard. Engineering industries focus on design and product development. These industries comprise a network of suppliers that SMEs play an essential role in supplying the quality parts and components to support the multinational firms' exporting activities. Process industries, particularly chemicals and basic metals, are stable and undifferentiated products, requiring large-scale facilities and innovation to improve the equipment and instruments.

This finding addresses that Cambodia accommodates many medium-tech and high-tech industries, which require good science and technology infrastructure to support their innovation and diffusion in the Cambodian economy. Industrial development strategies should focus on these high-tech industries because they have many nearby products to diversify (Hausman et al., 2006). Andersen (2010) also explained why high-tech industries should be chosen for government intervention in industrial development strategies. He claimed that high-tech industries experience higher world demand than low-tech ones, so entrepreneurs expect to earn higher profits. In particular, investing in high-tech industries is expected to gain higher productivity growth than the low-tech ones.

On the other hand, he defined the term "development block" as combining the inter-related sectors. When firms in a given industry introduce the core of innovation, other firms imitate the core of innovation to produce differentiated products in the related sectors. Thus, developing a science and technology system to support high-tech sectors' growth will help create many new ones related to those high-tech sectors.

According to Freeman et al. (1988), the high-tech industries are the techno-economic paradigm branch, composed of a series of interrelated technology systems. This new techno-economic paradigm requires, develops, and diffuses the knowledge, skills, and experience, which create a favorable environment for entering into more differentiated products in the interrelated technological systems. In the transition period, when there is a change in the techno-economic paradigm, the whole inter-related technology systems also evolve and change under the previous paradigm. These technology systems are transformed through propagating the information-intensive, flexible, systemic, and science-based knowledge between production systems. This evolution results in the reconversion of new industries, the redesign of mature products and production processes, and the development of products and industries, introducing new technology systems derived from various knowledge and skills.

Latecomer countries like Cambodia can enter into the new technology systems because they require a low level of experience and management capabilities and a low level of investment capital (Perez et al., 1988). However, Cambodia needs a substantial level of locational advantage and stock of scientific knowledge and technologies. Cambodia has substantially improved the locational advantages, so scientific and technical knowledge plays a critical role that policy-makers need to consider. In Cambodia, the new technologies do not necessarily originate in large firms but small firms owned by entrepreneurs with adequate university training specializing in science-based industries. These firms could help develop the knowledge and skills necessary for the early growth and late growth stages. However, they become public and are sold at a specific price in the maturity stage.

According to Perez et al. (1988), even though Cambodia can enter into new high-tech industries, it needs to consider whether the indigenous knowledge and skills are still relevant when the technology cycles evolve. On the other hand, when the new high-tech industries move to the early growth and late growth stages, they require a higher demand of the investment flow and the stock of knowledge and skills to gain the trade specialization in those high-tech industries. Furthermore, the high-tech industry's success is not a matter of individual products' success but the success of a group of products, which shows the characteristics of interrelated new technological systems.

SEZs have been recognized to help promote the structural transformation into high-tech and medium-tech industries in Cambodia. It has 22 SEZs operating in different regions, such as Phnom Penh, Sihanoukville, Bavet, and Poipet (Warr et al., 2015). They have attracted FDIs in existing and new industries, which help to diversify the Cambodian economy. According to Caniels et al. (2004), industrial clusters can help upgrade technological capabilities at the firm level through five agglomeration advantages. Those advantages include economies of scale, scope, and transaction in production; economies of scale, scope, and transaction in new knowledge accumulation; knowledge spillovers through changing attitude and motivation; knowledge spillovers by developing human capital through learning by doing; knowledge spillovers through technology transfer. They help improve the firms' technological capabilities by providing well-trained personnel, supporting the collective training courses, promoting search through collaboration, and developing R&D activities.

Cambodia appears at the early stage in developing the industrial clusters to support technological capabilities at the firm-level. These supporting activities are in various forms, including staff training programs, technology spillovers through cooperating with institutions and other firms, subcontracting with foreign exporting firms, and interacting with clients and suppliers using email and website, in addition to investing in R&D activities (Chapter 4). Cambodia should afford to develop the matchmaking services and information and the supplier development programs to help build the firm capabilities through these five agglomeration advantages. This public support can increase the critical mass of the Schumpeterian entrepreneurs so that Cambodia can increase its degree of specialization toward highly specialized high-tech industries.

5.5 Conclusion

Cambodia has a less developed national science and technology system to support organizational and technological capabilities in high-tech sectors than neighboring countries since its industrial transformation is weaker than those economies. Cambodia diversifies its economic structure toward high-tech sectors, such as electronics, automotive, engineering, LT products other than garment, and resource-based products, even though it still highly relies on the garment and agriculture sectors. In terms of high-tech industries, Cambodia has four growing, 16 emerging, 11 marginal, and 23 losing industries, while it has 11 growing, 12 emerging, 71 marginal, and 11 losing industries in terms of low-tech industries. This industrial transformation is still simple compared to the neighboring countries. Thailand is transforming its economic structure more deeply into the electronics, automotive, and engineering sectors, particularly in the automotive sectors. However, it still depends on low technology and resource-based manufactures. Vietnam transforms itself into electronics, other HT, automotive, engineering sectors, particularly electronics, but with a lower complexity level than Thailand. However, it still relies on low technology manufactures and agriculture.

Cambodia has concentrated in only a few established industries, particularly in garment, footwear, and travel goods, representing about 80% of total exports during 2016-2019. It has widened its specialization pattern slightly with the slow mobility within and between sectors over an extended period, particularly with more pronounced in high-tech industries. However, it starts to concentrate on the new sectors in the last two periods. Cambodian industries show stickiness and incremental change, which means that the initial less specialized industries move slowly to the average; meanwhile, the initial high specialized industries move back to the average within industries. They also reveal the slow mobility between sectors toward the sectors with a broad pattern of specialization.

The slow movement between industries in the last two periods may result from the lack of long-term oriented entrepreneurs with adequate organizational and technological capabilities to accelerate the movement speed between sectors toward the more narrow specialized high-tech industries. This finding supports the claim that Cambodia's science and technology system is emergent, which cannot upgrade and mobilize the critical mass of the nationalistic and long-term entrepreneurs to contribute to the industrial transformation.

Cambodia has also developed industrial clusters, which help to upgrade technological capabilities by providing staff training programs, promoting searching for new knowledge and technologies through cooperating with institutions, domestic firms, foreign firms, clients, and suppliers, in addition to investing in R&D activities. According to Caniels et al. (2004), Cambodia needs to adopt selective innovation policies to focus on three different ways to promote industrial competitiveness. First, the object of policy should be set to stimulate dynamic technological learning by positioning the clustered firms in the GVC governance forms for providing the support to upgrade specific firm capabilities. Second, the geographical coverage should be concentrated on the industrial clusters rather than on industries in general since agglomeration effects help leverage firms' technological capabilities in the industrial clusters. Third, a small number of progressive firms should be selected as a target for implementation to diffuse the broader impact, so resources can be reserved to increase the scope of interventions to promote industrial specialization even further.

Cambodia adopted the rice policy in 2010 and implemented it successfully since Cambodian rice's trade specialization moved from quadrant without trade specialization in the first period to quadrant with trade specialization. This kind of sectoral policy could be applied to other potential high-tech sectors found above since developing them will help promote the industrial transformation deeply into high-tech industries. Sectoral innovation policies should be adopted to upgrade the sectoral innovation systems to support the specific sectors, including four growing high-tech sectors. They also include 14 emerging high-tech industries, including five emerging electronics, four emerging process, and five emerging engineering sectors. Two other product subgroups should also be considered to choose for the target of the sectoral innovation policies. Eleven marginal sectors, which have NTS negative in both periods but increasing, include two other HT and nine medium-tech. In addition, among 23 losing sectors, there are also four losing ones with NTS between -0.5 and 0, which should be chosen. These industries will contribute to the industrial restructuring if sectoral innovation policies are developed to target them.

Chapter 6: Transformation of Competitive Advantage in Cambodia - Analysis of Trade and Technological Specializations of High-tech Sectors

6.1 Introduction

Competitive industries are essential to sustain economic growth in both developed and developing countries. In promoting these competitive industries, it is necessary to understand the patterns of trade and technological specializations in those industries and their relationship over time. The pattern of technological specialization has been explored extensively for developed countries (Archibugi et al., 1992 and 1994), while Dalum et al. (1996) has studied the pattern of trade specialization by analyzing it with the intra-country across industries and intra-industry across countries on the 20 OECD countries. Later, Uchida et al. (2005) applied research methodology similar to Dalum et al. (1996). Still, they focused on analyzing both patterns and their relationship in seven less and more advanced East Asian countries. However, few studies have been done to understand trade and technological specializations and their causal relationship in the early industrializing countries. The lack of research on this topic in developing countries may be due to the presence of few patents in developing countries, which is the main element to calculate the revealed technological specialization index. In Cambodia's case, there is no study to explain these patterns and their relationship over time to the extent of my knowledge.

Chapter 6 aims to analyze trade and technological specialization patterns of high-tech industries and their relationship at the national and industry levels. Cambodia's science and technology system is still incipient. Cambodia is experiencing industrial transformation with a little technological change to support its transformation. In general, Cambodia has a concentration pattern of trade specialization on a few traditional industries. Cambodia shows the elements of stickiness and incremental change in high-tech industries, in which the initial values of trade specialization move slowly toward the average within sectors. Also, there is mobility between sectors toward the broad pattern of trade specialization. Cambodia experiences a slight diversification of trade specialization in the long period, but it has started to concentrate its industries with a slow movement in the last two periods. On the other hand, Cambodian high-tech industries reveal a slight diversification and significant change of the technological specialization pattern over a long period. This finding suggests that Cambodia has been diversifying its industries into high-tech ones to catch up with the more advanced countries. In the relationship analysis, trade influences technology, which is common in the late industrializing countries applying the method of "learning by doing" through the linkage between multinational firms and domestic economy to develop their priority sectors.

In the relationship at the industry level, only two high-tech industries have both trade and technological specializations in the second period, moving from the quadrant without both advantages. Twenty high-tech industries appear in the upper left quadrant with a trade advantage in the second period, in which 14 sectors emerge from the quadrant without trade advantage in the first period. Four sectors are path-dependent trade advantage, and two sectors are path-dependent trade and technological advantages.

The study of trade and technological specialization patterns and their relationship helps us understand the sectoral distribution of trade and technological specializations, which is important to develop the sectoral innovation systems to support the specific sectoral trade specializations.

This chapter is developed as follows. In Section 6.2, we focus on the theoretical framework and the empirical evidence as a basis for analyzing the patterns of trade and technological specializations at the national and industry levels. Data and research methodology will be reviewed in section 6.3 to adopt the appropriate research methodology for analyzing the data for answering the above research purposes. Section 6.4 will show and discuss the results, and section 6.5 concludes.

6.2 Conceptual framework and the empirical evidence

It is necessary to have the conceptual framework to explain the economic structure using the trade data. When we want to understand the relationship between microeconomic activity level and macroeconomic performance, it is difficult to apply the neo-classical economic approach since its economic theories cannot explain the causal relationship. Therefore, we propose the alternative conceptual framework proposed by Dosi et al. (1990). They developed an alternative model of the relationship between technology and trade based on the differences in technological capabilities in terms of input efficiencies, product qualities, and innovative performance across countries. This alternative model can explain the causal relationship between the neo-classical economists' micro-foundations and the Keynesian approach's macroeconomic activity. According to this alternative model, to realize the change in aggregate macroeconomic activity, the government needs to respond by building competitiveness in innovativeness, input efficiencies, and domestic firms' organizational competencies.

Dosi et al. (1990) relied on four stylized facts to explain their model. First, the international distribution of innovation efforts and innovation results is significantly different between countries. Only a dozen countries still stay as members of the club of innovative countries in the last century. This fact is similar to the finding of Mani et al. (2004) showing that only five developing countries represent the major exports of high technology products. The technological capabilities vary among these high-tech exporting countries. While South Korea and Singapore have high design and manufacturing capabilities in high-tech products, Malaysia stays somewhere in the middle and Thailand and the Philippines in the low end. Nonetheless, developing countries as a whole are catching up very fast with developed countries.

The degree of the innovativeness of the different countries depends on the interplay between three factors i) science-based opportunities in the scientific community ii) country-specific and technology-specific institutions, and iii) nature and intensity of economic stimuli such as the factors influencing the replacement of labor for machines and the abundance or scarcity of economic inputs (Dosi et al., 1988). The concept of improving innovativeness is similar to the sectoral and national innovation system concepts proposed by Lee et al. (2018). To analyze the latecomer countries' economic catch-up process, they applied the above concepts, which function as an evolutionary process. Firms need to upgrade both the production and innovation capabilities that can be supported by themselves and by the sectoral and national innovation systems. These approaches can help explain how domestic firms catch up with the frontier firms by addressing market failures, capability failures, and system failures. In this sense, public policies that support the firms with the economic, technological, and scientific infrastructures can help the firms build their catching-up capabilities.

Second, the differences in innovative capabilities derive mainly from the increased labor productivity rather than the increased ratio of capital and output. In other words, the international production system's feature is represented by the differences in production functions rather than by the differences in endowments. Over time, a country has experienced both capital and technological accumulations, improving input efficiencies and facilitating searching and learning processes through feedback (Dosi et al., 1988). In this regard, the fundamental inter-national differences rely on learning and technological accumulation instead of the differences in endowments.

Nelson and Winter (1982) and Katz (1984) stressed that in the developing countries the gradual process of the entrepreneurial build-up of the technological capabilities could not help leapfrog into new industries or jump immediately into the export-oriented industrialization process. Moreover, the user-producer interaction introduced by Lundvall (1992) is relatively weak in LDCs because of their vulnerable capital goods sector. Finally, they don't have adequate institutional frameworks for supporting the evolution of the sectoral and national innovation systems to respond to the systematic problems for developing the capital goods sector.

Third, cross-sectoral analysis shows the opportunities and propensities to innovate in specific sectors and inter-sectoral distribution patterns of a country's innovative strengths and weaknesses. Inter-sectoral technology gaps/leads within countries yield the relative specializations in sectors with comparative advantages. The degree of mobility within and between industries depends on the level of technological opportunities, accumulativeness, and appropriability of those sectors. Lee et al.

(2018) suggested the long-term detour, which is a path that latecomers can leapfrog from low-end segments to high-end ones, which are short-cycled technologies. Latecomers can succeed in this strategy by capturing the windows of opportunities such as new technological paradigms, new demand, and new institutional settings.

According to Perez et al. (1988), latecomer countries can enter into new technology systems because they require a lower requirement of experience and management capabilities and a lower investment capital level. However, they need the locational advantages and the appropriate level of scientific and technical knowledge. Assume that the government has developed sufficient locational advantage. Then, scientific and technical knowledge plays an important role in promoting new firms' entry into new technological systems. In developed countries, the genuinely new technology systems are not necessarily originated in large firms but also formed in small firms owned by entrepreneurs or run by managers with adequate university training in science-based industries. These firms help build the knowledge and skills private in nature, which are necessary for the early growth and late growth stages. Later, in the maturity stage, the knowledge and skills become public and are sold at a specific price. This phenomenon implies that the well-qualified university personnel can open the windows of opportunity to produce new products in the new technology systems at the early phase. However, the problem here is whether the endogenous generation of knowledge and skills can assure subsequent success when the technology systems evolve. Successful technology systems require not only sufficient technological efforts but also adequate flows of investment. This development process is not about the individual product's success but the success of interrelated technology systems in evolution, ensuring the self-sustained growth process.

Fourth, in the case of trade flows, long-term changes in national patterns of revealed comparative advantages could be observed and linked to the nation-wide changes of the country's world market share in almost all sectors. Intra-sectoral technology gaps/leads between countries yield the tendency to adjust each country's world market share. This adjustment process is the notion of the absolute advantage or the structural competitiveness of each country. According to the empirical evidence, there is a significant relationship between the absolute advantages/ disadvantages and the world market shares (or per capita exports). The higher the degree of innovativeness of each sector of a country, the higher its world market share. In other words, the changes in technological capabilities can help increase the world market shares of a nation. This relationship is theoretically consistent with a determination of the domestic demand and the foreign trade multiplier. From the dynamic perspective, the evolution of a country's innovative/imitative capabilities can explain the trends of the growth rates of the tradable sector of that economy (Dosi et al., 1988).

Archibugi et al. (1992 and1994) found the convergence in aggregate data in R&D intensity (R&D as a percentage of GDP), in patenting intensity (external patenting per US$ of exports), and in bibliometric indicators (number of the published articles and citations). However, they found some concentration patterns of technological specialization in the disaggregated data. In developing countries, Uchida et al. (2005) showed the empirical evidence for proofing the trade and technology model of East Asian developing countries. Analysis at the country level indicates that the differences across the East Asian developing countries are more pronounced in the pattern of technological specialization than trade specialization. Cumulative and path-dependent technological specialization is seen to a larger degree in Hong Kong, South Korea, and Singapore than in other East Asian countries, which addresses the former's economic prosperity. However, the latter are experiencing the diversification and changes of technological specialization patterns, suggesting that they are transforming their industrial structure into higher value-added industries to catch up with the leading economies in the region. On the other hand, trade specializations are characterized as cumulative patterns in all economies, stable and concentrated.

When both patterns are analyzed at the industry level, the result shows that Hong Kong experiences a more robust path-dependent pattern of technological specializations in many industries. Still, most of them are in low-tech and medium-tech industries. On the other hand, South Korea and Singapore have healthy path-dependent technological specializations in few industries but high-tech ones. For other East Asian developing countries, trade and technological specializations are established in a narrow range of industries.

The relationship between trade and technological specializations shows that technological specialization supports trade specialization in advanced East Asian countries; however, the reversed causalities occur for the less developed ones. The finding suggests that trade success is important to improve technological specialization by using learning by doing approach.

6.3 Data and Research Methodology

To understand the changes in and the relationship between trade and technological specialization patterns, we calculate the indices of trade specialization and technological specialization using the trade data from the international trade center's website: www.intracen.org. Since this trade data uses a harmonized system to code their industrial categories, which are different from Standard International Trade Classification (SITC version 3), we need to develop a concordance table based on the conversion table applied in the UN Comtrade. This chapter uses the product classification by technological categories developed by Lall (2000) to construct the concordance table. According to this concordance table, we can construct net trade specialization and technological specialization indices on 90 high-tech industries for Cambodia. Then we do the regression on both indices to understand the patterns of trade and technological specializations and their relationship at the national and industry levels. We also apply the same calculation for Thailand and Vietnam.

In this chapter, we apply the research methodology developed by Uchida et al. (2005). Their study used the traditional revealed comparative advantage (RCA) proposed by Balassa (1965) and the technological specialization index, which uses the number of patents as a base to calculate. Instead of using RCA, we use the net trade specialization index (NTS) proposed by Iapadre (2011). He thought that NTS is a better measurement than the former indicator to analyze the trade specialization patterns since NTS includes import and export data to calculate the indices. NTS can also solve the normality problem, which happens to the Balassa measure.

$$NTS_{i,j} = \frac{\frac{X_{i,j}}{X_{i,q}} - \frac{M_{i,j}}{M_{i,q}}}{\frac{X_{i,j}}{X_{i,q}} + \frac{M_{i,j}}{M_{i,q}}}$$

X and M are the amount of export and import, respectively. i and j represent countries and sectors. Besides, q represents the sum of sectors. In this formula, the value of $NTS_{i,j}$ is between -1 and +1.

Since Cambodia has a few patents as a base to calculate the index of technological specialization, we use a new formula that uses trade data as a base to calculate the indices (Alcorta et al., 1998). However, this new formula allows us to calculate only on the 90 high-tech industries. These new indices can be used to analyze the technological specialization pattern of Cambodian high-tech industries.

$$MS_i^H = \frac{\sum_{J \in H} X_{ij}}{\sum_{J \in H} X_j} \quad , \quad MS_i^L = \frac{\sum_{J \in L} X_{ij}}{\sum_{J \in L} X_j}$$

$$ITS_i = \frac{MS_i^H}{MS_i^L}$$

Where i and j stand for countries and SITC product groups, respectively. X_{ij} is the export amount from countries i in SITC product groups j, while X_j stands for total export of SITC product groups j. While H and L stand for the set of high technology and low technology product groups, MS_i^H and MS_i^L are the market share of the export of high technology and low technology product groups, respectively. ITS_i is the index of technological specialization. If the index is equal to one, Cambodia's export share of the high-tech industry is equal to its export share of all low-tech industries. So, Cambodia doesn't have technological specialization in the high-tech industry. If $ITS_i > 1$, it means that Cambodia is strong in technological specialization of the high-tech industry. If $ITS_i < 1$, it means that technological specialization in the high-tech industry is weak.

For testing the stability pattern of technological specialization, the Balassa measure may result in a normality distribution problem since the index's value ranges from zero to infinity, and the (weighted) average equal to one. Balassa (1965) applied the logarithmic transformation for the index; however, this method still has a disadvantage because it results in a tremendous negative value. Laursen et al. (1995) coped with the logarithmic transformation's disadvantage by developing a new measure called "reveal symmetric comparative advantage" to resolve the normality problem. This new index was also applied by Uchida et al. (2005) to transform the revealed comparative advantage (RCA) and revealed technological advantage (RTA) to become the revealed symmetric comparative advantage (RSCA) and revealed symmetric technological advantage (RSTA).

In this chapter, we applied the new index of technological specialization used by Laursen et al. (1995) and Uchida et al. (2005). It is transformed into the symmetric index of technological specialization to resolve the normality problem.

$SITS_i = \frac{ITS_i - 1}{ITS_i + 1}$

Where the value of $SITS_i$ is between -1 and +1

We use the bivariate Galtonian regression on the two following equations to analyze the distribution of trade and technological specializations (Uchida et al., 2005).

$NTS_{ij}^{t} = \alpha + \beta NTS_{ij}^{tn} + e_{ij}^{t}$ (1)

$SITS_{ij}^{t} = \alpha + \beta SITS_{ij}^{tn} + e_{ij}^{t}$ (2)

Where i stands for countries, and j stands for product groups. High technology industries, such as high and medium technology industries, have 90 product subgroups with a three-digit level of SITC version 3. Low technology industries have 163 product subgroups with a three-digit level of SITC version 3. They include low technology products, resource-based manufactures, and primary products,

We divide the two indices into four periods: period I (2001-2005), period II (2006-2010), period III (2011-2015), and period IV (2016-2019). t represents period IV, while tn represents previous periods III, II, and I.

If β=1, the specialization pattern remains unchanged. Furthermore, when β>1, the existing pattern of specialization is strengthened. This condition means that competitive industries become more specialized and differ significantly from less competitive industries, which become even less specialized. When 0< β<1, the existing pattern of specialization is cumulative and has changed incrementally. It means that the initial low value of NTS or SITS increases slowly to the average, while the initial high value of NTS or SITS decreases slowly back to the average within sectors. So, the difference between highly competitive and less competitive industries becomes smaller. On the contrary, when β < 0, the pattern of specialization is reversed. The NTS or SITS that initially is below the average becomes the above-average one in the final period and vice-versa. The magnitude of (1- β) is called the regression effect. When the regression effect (1- β) is low (high β), the specialization pattern is concentrated in a few industries. When the regression effect (1- β) is high (low β), it is more diversified.

We use the variance β/ρ to measure the degree of specialization, which is the extent of dispersing technological or trade specialization distribution. ρ is the correlation coefficient. Regarding to Hart (1976), with the formula: $\rho = 1 - \frac{\sigma_\varepsilon^2}{\sigma_t^2}$, we have: $\frac{\sigma_i^{2t}}{\sigma_i^{2nt}} = \frac{\beta^2}{\rho^2}$ or $\frac{\sigma_i^{t}}{\sigma_i^{nt}} = \frac{|\beta|}{|\rho|}$. When the coefficient β is larger than the correlation coefficient ρ (β/ρ > 1), the degree of specialization has increased, which is equivalent to the increase in dispersion. When β < ρ or β/ρ < 1, the degree of specialization has decreased, which is equivalent to the decrease in dispersion. When β = ρ, it has not changed. Coefficient β < 1 represents the change from the initial value of specialization toward the average within sectors. If this change is outweighed by the mobility effect (β > ρ), it represents the significant change of proportional position between sectors toward the specialized sectors. In contrast, if the change is not outweighed by the mobility effect (β < ρ), it represents the slow mobility between sectors toward the broad pattern of specialization.

The Pearson correlation coefficient ρ is used to measure industries' mobility up and down in NTS and SITS distribution. The magnitude of (1 – ρ) is called the mobility effect. When the mobility effect (1 - ρ) is low (high ρ), the industries' relative position has little changed. However, when the mobility effect (1 - ρ) is high (low ρ), the industries' relative position has changed significantly. This significant change means that some industries move closer together, while some industries shift away from one another. While the industries are characterized by stability (weak mobility effect) and concentration (weak or negative regression effect), the established industries have been strengthened. On the other hand, while the industries are characterized by change (high mobility effect) and diversification (a high regression effect), it means that the pattern of specialization has changed.

6.4 Results

6.4.1 Analysis of Pattern of Technological and Trade Specialization at the Aggregate Industry Level

The pattern of technological specialization can be analyzed only for high-tech industries because we cannot use the new formula of the SITS index proposed by Alcota et al. (1998) to calculate the SITS for low-tech sectors. Table 6.4.1.1 shows the indices of technological specialization of HT product subgroups for the four periods for Cambodia, Thailand, and Vietnam. As has been shown, Cambodia reveals weak technological advantages for all product subgroups in all periods. However, HT in electronics and MT in automotive and engineering seem to be improved, and other HT and MT in the process stay stagnant during the four consecutive periods. On the contrary, Vietnam shows significant technological specialization in high-tech industries, particularly in electronics, while other HT and MT in automotive and engineering show improvement. Thailand offers significant technological specialization in all high-tech product subgroups except other HT. This finding suggests that Cambodia is early in promoting the science and technology system to support its high-tech industries compared to Vietnam and Thailand.

Table 6.4.1.1 SITS Indices of High-tech Industries in the Aggregate Level

Period	I	II	III	IV	I	II	III	IV	I	II	III	IV
	Cambodia				Thailand				Vietnam			
HT	-0.99	-0.98	-0.92	-0.89	0.27	0.36	0.29	0.23	-0.57	-0.26	0.25	0.32
Electronics	-0.99	-0.99	-0.90	-0.85	0.43	0.48	0.42	0.35	-0.42	-0.11	0.39	0.44
Other HT	-0.97	-0.98	-0.98	-0.99	-0.49	-0.45	-0.46	-0.42	-0.93	-0.81	-0.56	-0.44
MT	-0.96	-0.87	-0.82	-0.82	0.04	0.18	0.26	0.24	-0.70	-0.49	-0.38	-0.43
Automotive	-0.97	-0.77	-0.57	-0.66	-0.10	0.23	0.35	0.33	-0.78	-0.76	-0.72	-0.77
Process	-0.94	-0.96	-0.95	-0.93	0.09	0.18	0.26	0.19	-0.66	-0.52	-0.40	-0.53
Engineering	-0.97	-0.89	-0.92	-0.86	0.08	0.15	0.22	0.21	-0.67	-0.37	-0.24	-0.27

Note: HT: High technology manufactures, MT: Medium technology manufactures

Source: International Trade Center, 2020

Table 6.4.1.2 shows trade specialization indices at the aggregate industry level for Cambodia, Thailand, and Vietnam. In Cambodia, product groups in high and medium technologies have lost the trade specialization for all the periods. When product groups are divided into further subgroups, Cambodia has its electronics industries achieve significant trade specialization in the last two periods. In the meanwhile, other HT product and MT product subgroups lose their trade specialization for all periods. However, the latter shows the improvement of NTS in general, particularly significant are in the automotive and engineering industries.

Cambodia has achieved the trade specialization at a lower level than the neighboring countries. Thailand has its electronics industry gain NTS during all the periods, while its other HT loses trade specialization and is stagnant, resulting in a small loss of NTS in HT industries in the last period. Thailand shows small positive trade specialization in the MT industries for the last three periods. This improvement derives from the significantly positive trade specialization in automotive sectors accompanied by the process and engineering sectors' progress though from a low base.

Vietnam is increasing its trade specialization in HT industries from a low base to a small positive one in the last period. This improvement emerges from the progress of both electronics and other HT, particularly in electronics. For MT industries, Vietnam shows a significant loss of trade specialization. However, their NTS is improved significantly over time, particularly in the automotive and engineering industries.

Table 6.4.1.2 NTS Indices at the Aggregate Industry Level

Product groups	I	II	III	IV	I	II	III	IV	I	II	III	IV
	Cambodia				Thailand				Vietnam			
HT	-0.93	-0.94	-0.68	-0.35	0.05	0.07	0.01	-0.02	-0.36	-0.15	-0.02	0.02
Electronics	-0.78	-0.64	0.38	0.65	0.10	0.11	0.07	0.03	-0.12	-0.07	0.02	0.04
Other HT	-0.93	-0.91	-0.92	-0.90	-0.38	-0.33	-0.45	-0.38	-0.90	-0.66	-0.43	-0.26
MT	-0.93	-0.78	-0.73	-0.68	-0.07	0.03	0.06	0.10	-0.76	-0.56	-0.44	-0.39
Automotive	-0.92	-0.62	-0.36	-0.50	0.24	0.45	0.43	0.48	-0.65	-0.49	-0.27	-0.35
Process	-0.96	-0.96	-0.95	-0.91	-0.22	-0.15	-0.04	-0.09	-0.86	-0.75	-0.65	-0.67
Engineering	-0.85	-0.71	-0.81	-0.63	-0.08	-0.04	-0.05	0.01	-0.69	-0.43	-0.31	-0.25

Note: HT: High technology manufactures, MT: Medium technology manufactures

6.4.2 Analysis of the Patterns of Trade and Technological Specialization at the National Level

Table 6.4.2.1 shows the indices of technological specialization obtaining from the regression on equation (2). In general, Cambodian high-tech industries experience the concentration pattern of specialization in a few established ones. In Cambodia, technological specialization has changed incrementally in the last two periods because the coefficient $\hat{\beta}$ is significantly less than one at the p-value=0.01 level but not significantly different from zero. The values of the degree of specialization less than one show that Cambodia has experienced a decrease in dispersion in the specialization distribution, which means that it has slow mobility between sectors toward the broad specialization pattern. In the long period IV-I, it has a slight diversification of specialization and a significant mobility effect of the technological specialization. This pattern suggests that Cambodia is increasing its specialization pattern, maybe due to the increase of foreign direct investments in high-tech industries. However, it starts to concentrate on the established high-tech sectors in the more recent periods since the value of regression and mobility effects becomes lower.

Thailand and Vietnam show slightly different results. Their technological specialization pattern offers slight diversification in a long period but slow mobility between sectors. Their degree of specialization is also larger than that of Cambodia, suggesting that they have a larger increase in the specialization distribution dispersion. This means that their mobility between sectors is faster toward the broad specialization pattern. They also tend to concentrate stronger on the established industries than Cambodia since their regression and mobility effects become much lower. Vietnam shows that the values of $\hat{\beta}$ are not significantly different from 1 but significantly different from zero, representing only the cumulative specialization pattern but not incremental change. On the other hand, Thailand represents the cumulative and incremental change in the specialization pattern.

Table 6.4.2.1 SITS Indices of High-tech Industries

Period	$\hat{\beta}$	Degree of Specialization	Regression Effect	Mobility Effect
Cambodia				
IV-I	.1226*** (.1787)	0.1796	0.8774	0.3175
IV-II	.5657*** (.0972)	0.6165	0.4343	0.0824
IV-III	.6322*** (.0660)	0.6566	0.3678	0.0372
Thailand				
IV-I	.7068***	0.7129	0.2932	0.0086

	(.0645)			
IV-II	.8500*** (.0470)	0.8539	0.1500	0.0045
IV-III	.9023** (.0438)	0.9059	0.0977	0.0039
		Vietnam		
IV-I	.8522 (.1289)	0.8808	0.1478	0.0324
IV-II	.9435 (.0710)	0.9528	0.0565	0.0097
IV-III	.9377 (.0453)	0.9414	0.0623	0.0039

Note: Period I = 2001-2005, Period II = 2006-2010, Period III = 2011-2015, Period IV = 2016-2019
*, **, *** = statistically significant at the 0.10, 0.05, and 0.01 level, respectively: H_0: β=1
The degree of specialization = $\hat{\beta}/\hat{\rho}$, the regression effect = (1-$\hat{\beta}$), the mobility effect = (1-$\hat{\rho}$)
Source: International Trade Center, 2020

Table 6.4.2.2 shows the Galtonian regression result of equation (1) on the NTS of high-tech industries. Cambodia shows an incremental change in trade specialization pattern since the value of $\hat{\beta}$ is significantly different from one. This means that there is a movement of initial values of NTS toward the average within sectors. The value of the degree of specialization less than one means that Cambodia experiences a decrease in the specialization distribution dispersion. This means that there is mobility between sectors toward the broad pattern of specialization. In general, Cambodia tends to become more concentrated on the established high-tech industries because the coefficient $\hat{\beta}$ is less than one, and the regression and mobility effects become lower. In the long run, it has a slight widening pattern of specialization but with a slow movement. Thailand and Vietnam have $\hat{\beta}$ bigger and the regression and mobility effects lower than Cambodia, they tend to concentrate more strongly in a few established high-tech industries. However, their values of the degree of specialization are higher, suggesting that they have a larger increase in the dispersion of the specialization distribution, which means that the mobility within and between sectors is faster toward the broad specialization pattern.

Table 6.4.2.2 NTS Indices of High-tech Industries

Period	$\hat{\beta}$	Degree of Specialization	Regression Effect	Mobility Effect
		Cambodia		
IV-I	.0126*** (.0985)	0.0128	0.9874	0.0131
IV-II	.2738*** (.1206)	0.2793	0.7262	0.0197
IV-III	.6473*** (.0983)	0.6558	0.3527	0.0130
		Thailand		
IV-I	.6302*** (.0606)	0.6352	0.3698	0.0078
IV-II	.8146*** (.0460)	0.8183	0.1854	0.0045
IV-III	.9427* (.0321)	0.9442	0.0573	0.0016
		Vietnam		

IV-I	.4273*** (.0856)	0.4327	0.5727	0.0124
IV-II	.7388*** (.0702)	0.7450	0.2612	0.0083
IV-III	.9279* (.0418)	0.9307	0.0720	0.0029

Note: Period I = 2001-2005, Period II = 2006-2010, Period III = 2011-2015, Period IV = 2016-2019
*, **, *** = statistically significant at the 0.10, 0.05, and 0.01 level, respectively: H_0: β=1
The degree of specialization = $\hat{\beta}/\hat{\rho}$, the regression effect = (1-$\hat{\beta}$), the mobility effect = (1-$\hat{\rho}$)
Source: International Trade Center, 2020

6.4.3 Analysis of the Patterns of SITS and NTS at the Industry Level

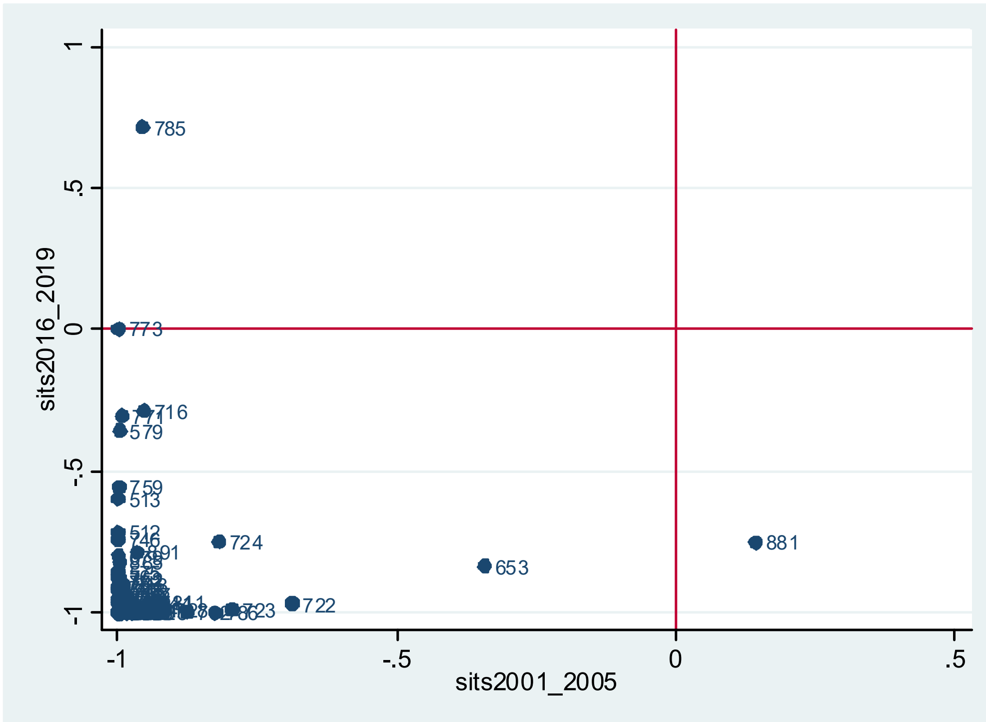
In figure 6.4.3, the industries located in the upper right quadrant represent cumulative technological or trade specialization. While industries in the lower right quadrant have lost technological or trade specialization, those in the upper left quadrant have gained it. Industries in the lower left quadrant have negative technological or trade specialization in both periods. Figure 6.4.3 shows that Cambodia reveals technological specialization in only Motorcycles & cycles (785) and Equipment for distribution electricity (773) in the last period; simultaneously, they also gain trade specialization in these two industries. Cambodia reveals the technological disadvantage in Photographic apparatus & equipment (881). None of the industries show path-dependent technological specialization. Fifteen high-tech industries with trade advantages emerge from the quadrant without technological advantage. They include five electronics, five process, and five engineering industries. Besides, four medium-tech industries with path-dependent trade advantage also emerge from quadrant without technological advantage. They include one automotive, one process, and two engineering sectors.

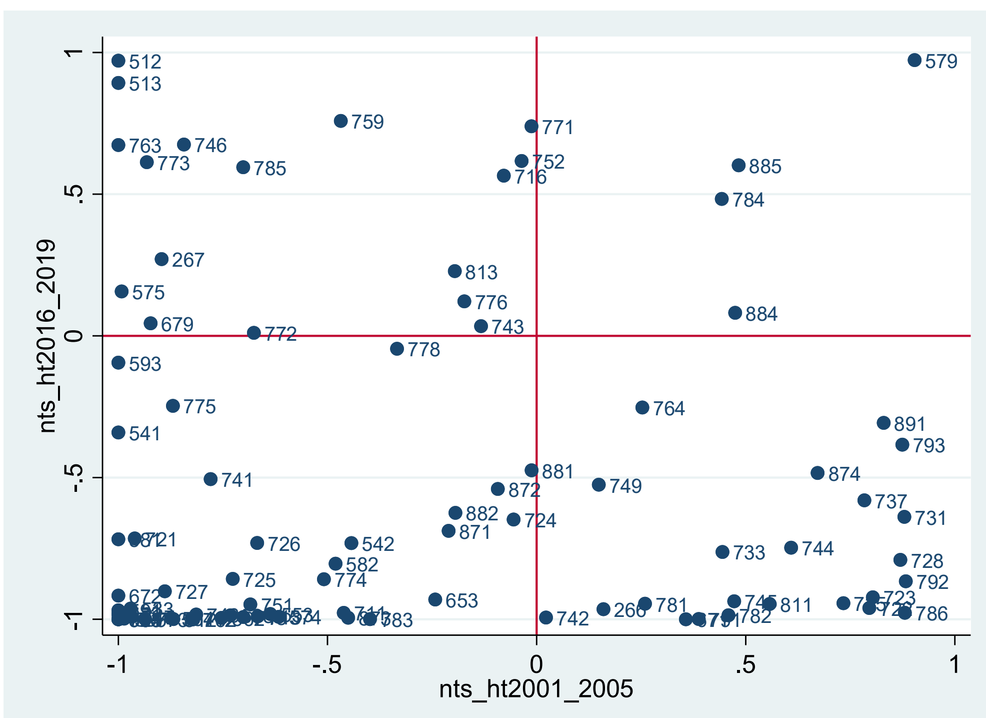
Thailand shows that 20 high-tech industries reveal path-dependent technological advantage, and they are also connected with path-dependent trade advantage. They include three electronics, one other HT, two automotive, eight process, and six engineering industries. Besides, two medium-tech sectors, including one process and one engineering, reveal path-dependent technological advantages. The two industries also relate to the trade advantage in the second period. In addition, two high-tech industries, such as one other HT and one process, emerge with technological specialization in the second period. The two industries are also associated with the path-dependent trade advantage. Moreover, seven high-tech industries that emerge with technological advantages in the second period are connected to trade advantage in the second period. The seven industries include two electronics, one process, and four engineering industries. In addition, a process industry with path-dependent trade advantage emerges from the quadrant without technological advantage in the first period. An engineering industry with trade advantage in the second period also emerges from the quadrant without technological advantage in the first period.

Vietnam's four high-tech sectors with the path-dependent technological advantage still have path-dependent trade advantage. Six high-tech industries with the technological advantage in the second period have supported these industries to gain the path-dependent trade advantage. Those industries include four electronics, one process, and one engineering. Besides, four high-tech industries emerge with technological advantages in the second period. They include two electronics and two engineering industries. The four industries are also associated with trade specialization in the second period. Moreover, four high-tech industries with path-dependent trade advantages emerge from the quadrant without technological advantage in the first period. The four industries include two process and two engineering industries. Finally, seven high-tech industries with trade advantage in the second period emerge from the quadrant without technological advantage in the first period. They include two other HT, one process, and four engineering industries.

Figure 6.4.3 Change in SITS and NTS Indices

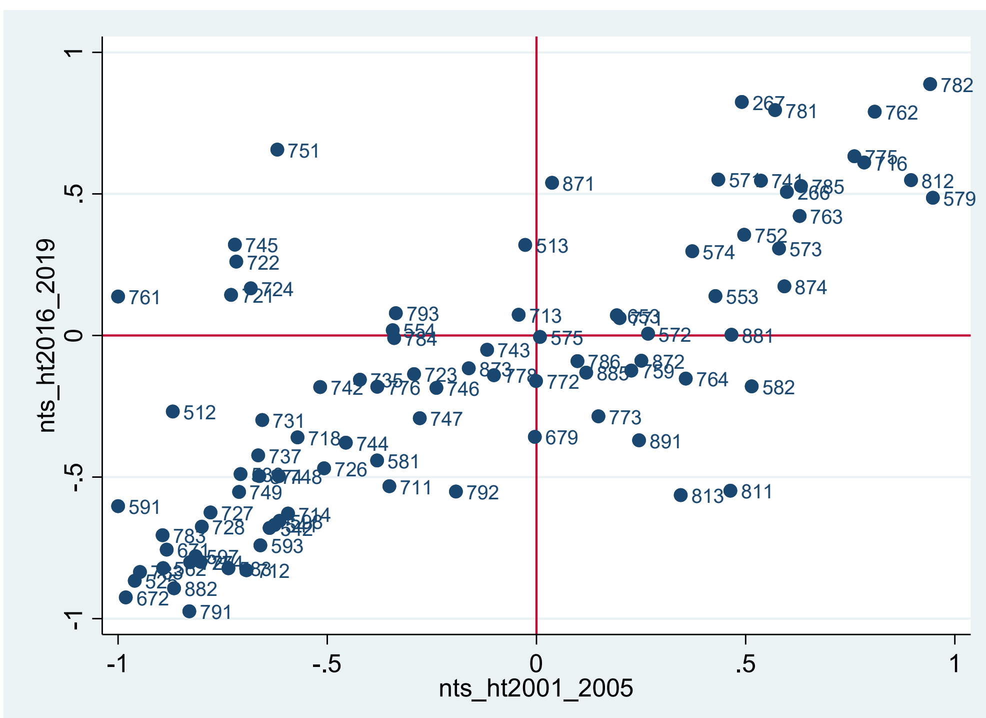
Cambodia



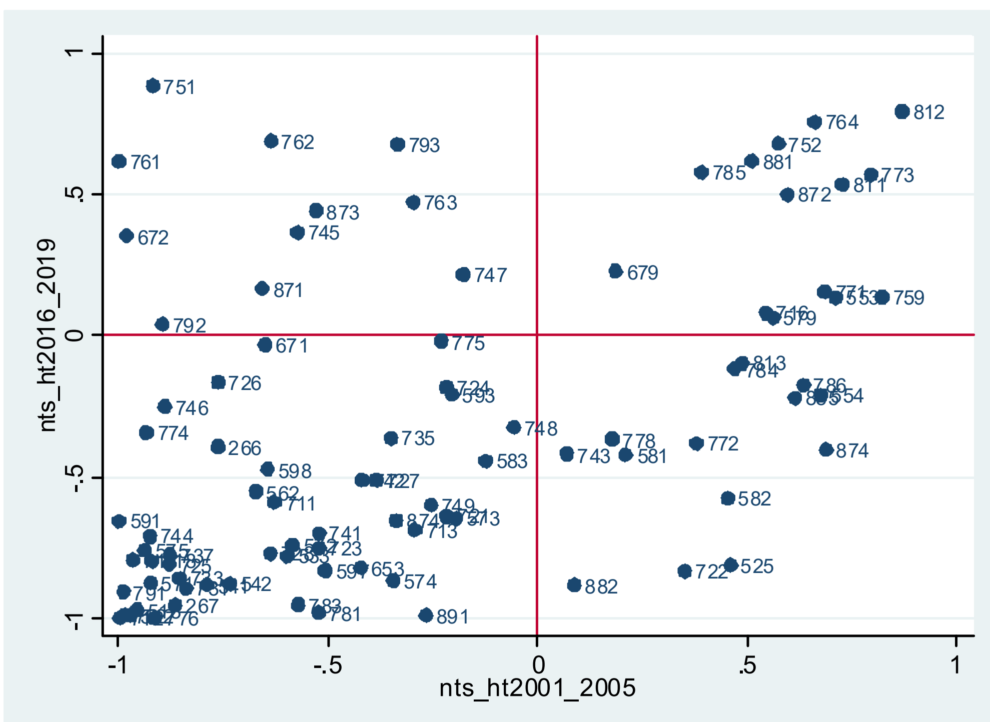


Thailand


sits_ht2016_2019
sits_ht2001_2005


nts_ht2016_2019
nts_ht2001_2005

Vietnam



Source: International Trade Center, 2020

6.4.4 Analysis of Causal Relationship between NTS and SITS for High-Tech Sectors

6.4.4.1 Analysis of the Relationship at the National Level

In this section, we regress NTS_t on $SITS_{t-1}$ and then $SITS_t$ on NTS_{t-1} to understand the causal relationship between NTS and SITS for three periods. Table 6.4.4.1 shows that trade influences technological development in Cambodia for the last two periods since the value of the correlation coefficient $\hat{\rho}$ and adjusted R-square are larger for the regression of NTS on SITS. However, technology seems to influence trade for the first period. This phenomenon can be explained as follow. In 2001-2005, Cambodia had a significant stock of technicians, engineers, and middle management that attracted domestic and foreign firms to invest in high-tech industries. However, when the number of domestic and foreign firms increased and absorbed all of them, the new domestic and foreign firms entering the high-tech industries late lack this kind of human capital and need to apply the learning by doing method to develop their production capabilities. On the other hand, Thailand and Vietnam show causal relationships between trade and technology throughout all the periods.

Table 6.4.4.1 Relationship between Trade and Technology

	Period	$\hat{\beta}$	$\hat{\rho}$	$\bar{R}^2$		Period	$\hat{\beta}$	$\hat{\rho}$	$\bar{R}^2$
Cambodia									
SITS to NTS	IV-III	.5949** (2.61)	0.9275	0.0611	NTS to SITS	IV-III	.2554*** (6.37)	0.9865	0.3077
	III-II	1.0153*** (4.43)	0.9045	0.1727		III-II	.2249*** (4.40)	0.9825	0.1804
	II-I	.9620** (2.60)	0.6999	0.0606		II-I	.0485 (1.33)	0.9869	0.0085
Thailand									
SITS to NTS	IV-III	.7463*** (11.00)	0.9903	0.5743	NTS to SITS	IV-III	.7547*** (10.71)	0.9898	0.5609
	III-II	.7418*** (11.51)	0.9914	0.5965		III-II	.6888*** (10.05)	0.9903	0.5293
	II-I	.6861*** (8.87)	0.9892	0.4659		II-I	.6083*** (8.60)	0.9905	0.4507
Vietnam									
SITS to NTS	IV-III	.7973*** (9.82)	0.9914	0.5174	NTS to SITS	IV-III	.6880*** (9.98)	0.9908	0.5254
	III-II	.8470*** (8.94)	0.9889	0.4700		III-II	.6677*** (10.33)	0.9914	0.5430
	II-I	.8985*** (6.35)	0.9752	0.3067		II-I	.3358*** (4.77)	0.9871	0.1967

Note: Period I = 2001-2005, Period II = 2006-2010, Period III = 2011-2015, Period IV = 2016-2019
*, **, *** = statistically significant at the 0.10, 0.05, and 0.01 level, respectively: H_0: β=0, t-statistics is in the parenthesis.
Source: International Trade Center, 2020

The trade specialization pattern shows a slight diversification and small change in the long run, but the technological specialization pattern shows a slight diversification but a significant change in the long run (Table 6.4.2.1). This difference may derive from the adequate number of skilled workers in the first period, which help increase the mobility between sectors toward the broad pattern of technological specialization faster in the first period than in the last two periods. Nonetheless, it is not the case for the pattern of trade specialization. This impact can be illustrated in table 6.4.4.1, which shows the significant effect of SITS on NTS, but the non-significant effect of NTS on SITS in the first period. This result suggests that Cambodia has depended on the learning by doing approach in developing high-tech industries rather than providing the public support to help upgrade firm capabilities of domestic firms investing in high-tech sectors.

6.4.4.2 Analysis of the Relationship of Patterns of NTS and SITS at the Industry Level

Figure 6.4.4.2.1 is constructed to understand the relationship between technology and trade comparative advantages for high-tech industries in two periods: 2001-2005 and 2016-2019. Industries in the upper right quadrant represent both trade and technological advantages, while those in the lower-left quadrant have no both advantages. Also, industries in the upper left quadrant gain a trade advantage, while those in the lower right quadrant gain a technological advantage.

Cambodia adapts to a pattern that trade influences technological specialization. As has been shown in Figure 6.4.4.2.1, it has no high-tech industries with both trade and technological advantages in the first period. It has 27 high-tech sectors with trade advantage in the first period. Among these sectors, only four sectors are path-dependent trade advantage, while the remaining 24 ones lose trade advantage in the second period. Only a sector, namely Photographic apparatus and equipment (881), appears in the quadrant with technological advantage in the first period but moves back into quadrant without both advantages in the second period. In the second period, two sectors reveal both trade and technological advantages. They include Motorcycles and bicycles (785) and Equipment for distributing electricity (773), emerging from the quadrant without both advantages in the first period. The success in these sectors may derive from the fact that Cambodia can attract foreign firms to invest in these sectors and develop them.

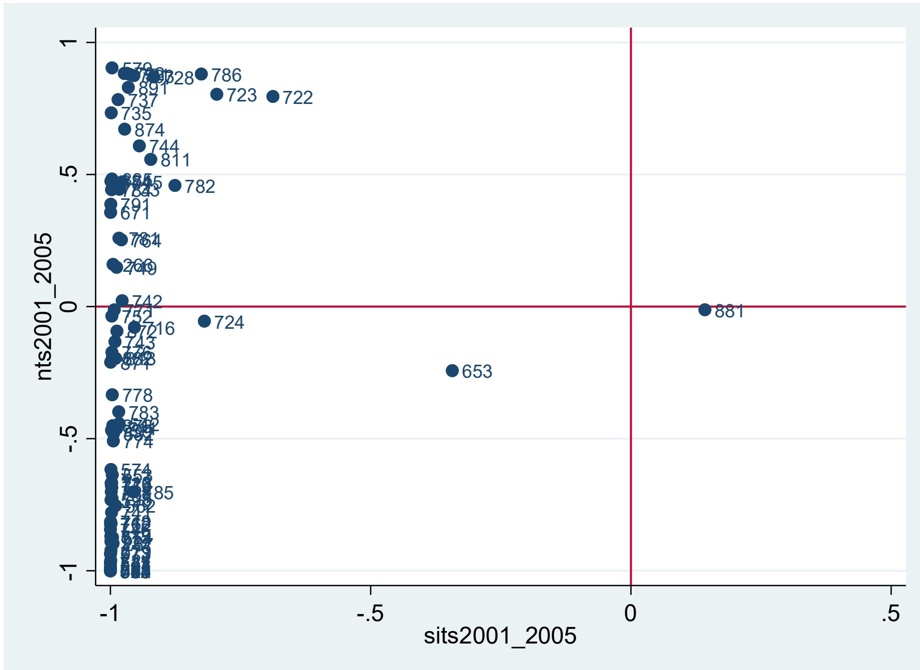
Furthermore, 20 high-tech industries have a comparative trade advantage in the second period. Among these sectors, four sectors are path-dependent trade advantage, 14 sectors emerge from quadrant without trade advantage, and two sectors are path-dependent trade and technological advantages. According to Uchida et al. (2005), high-tech industries with trade specialization without technological specialization usually operate as an assembly-type and are run by subsidiaries of multinational firms.

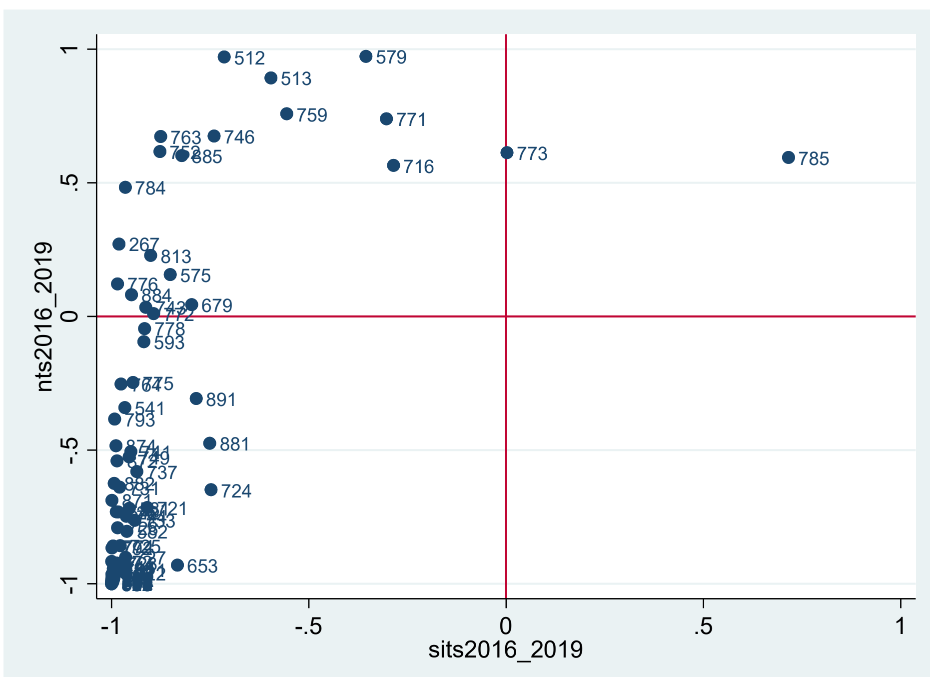
When compared with neighboring countries, Cambodia shows weaker causal relationship between technological and trade advantages. Thailand appears to have a stronger causal relationship. It reveals 20 high-tech industries with both trade and technological advantages in the first period and 31 high-tech sectors in the second period. Among these 31 high-tech industries, 20 high-tech industries represent path-dependent trade and technological advantages. They include four electronics, two automotive, eight process, and six engineering sectors. Besides, seven high-tech industries emerge from the quadrant without both advantages in the first period. The seven industries include two electronics, one process, and four engineering industries. In addition, two high-tech industries, such as one in other HT and one in automotive, emerge from the quadrant without the technological advantage in the first period. The other two medium-tech industries, one in process and one in engineering, emerge from quadrant without trade advantage in the first period.

Thailand also offers nine high-tech industries with trade advantage in the first period. Among them, two are path-dependent trade advantage, and two move to the quadrant with technological advantage. Another one sector moves to the quadrant with trade advantage. Furthermore, two high-tech industries with trade advantage in the second period include Polyethers and epoxide resins (574) and Agricultural machinery and parts (721). The former is a path-dependent trade advantage, while the latter emerges from the quadrant without trade advantage in the first period. There are seven high-tech industries with technological advantage in the first period. One engineering product moves to the quadrant with trade advantage, and four ones support the marginal industries in electronics and other HT in the second period. In the second period, sixteen high-tech ones with technological advantage include two electronics, one other HT, two automotive, three process, and eight engineering industries. Among these industries, seven high-tech ones are associated with the quadrant with trade advantage in the second period, and two are path-dependent trade advantage. In addition, four high-tech industries emerge from quadrant with trade advantage in the first period, and three emerge from quadrant without both advantages in the first period.

Figure 6.4.4.2.1 The Relationship between NTS and SITS from 2001-2005 and 2016-2019

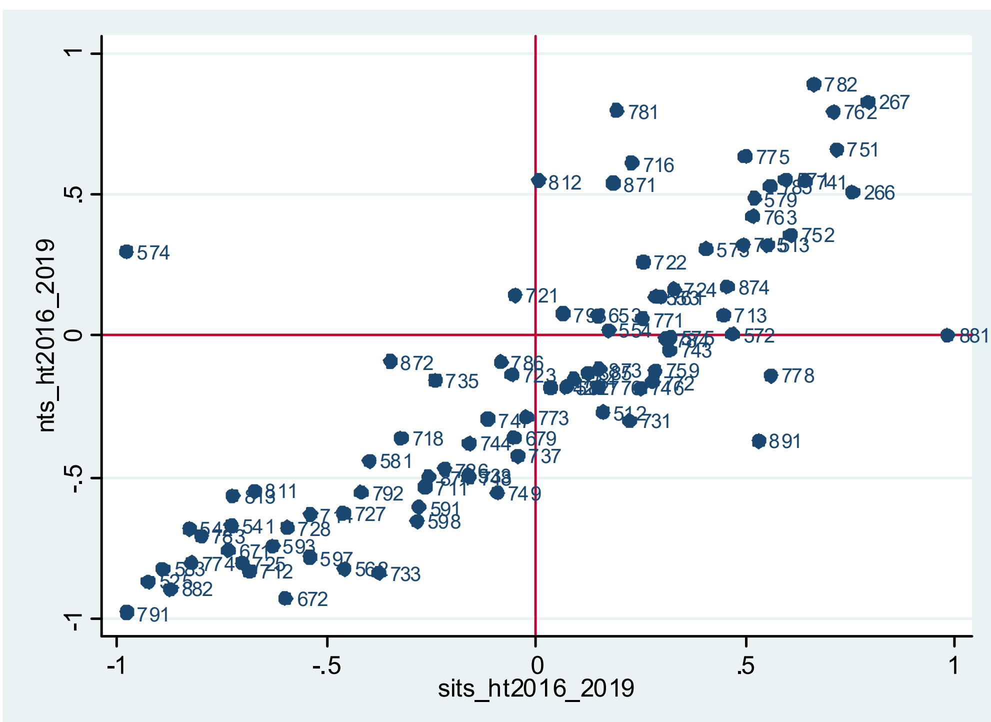
Cambodia



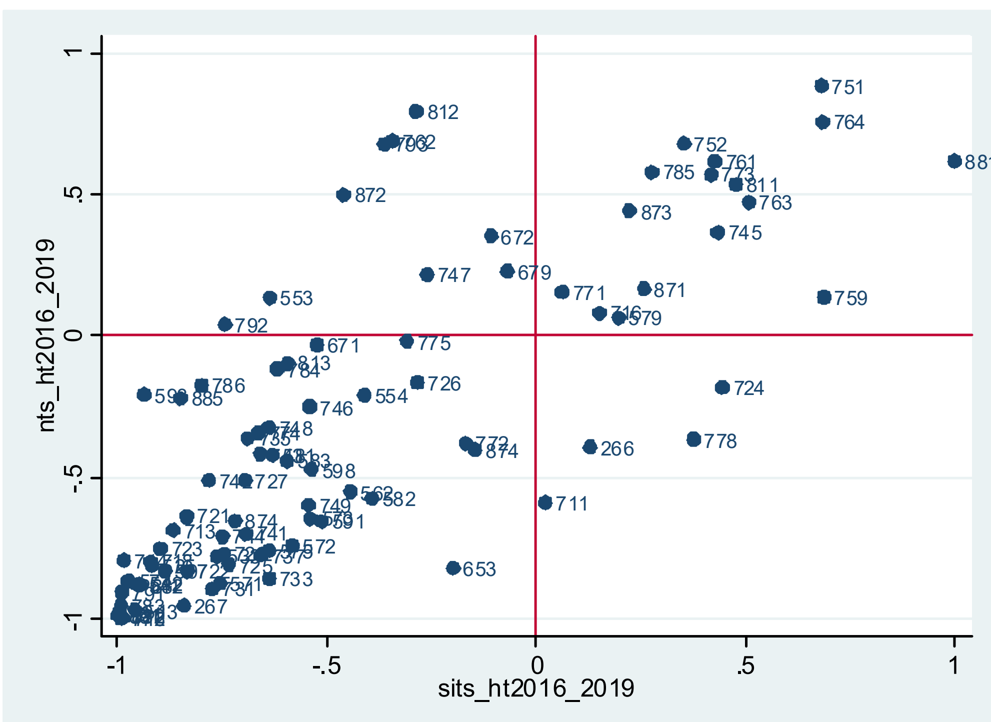


Thailand


nts_ht2001_2005
sits_ht2001_2005
-1
-.5
0
.5
1


nts_ht2016_2019
sits_ht2016_2019
-1
-.5
0
.5
1

Vietnam



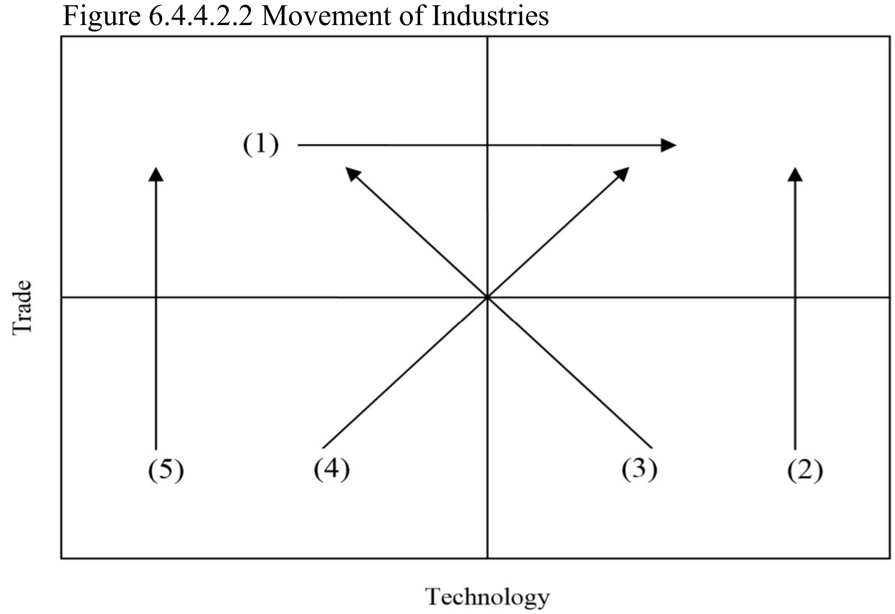
Source: International Trade Center, 2020

Vietnam also reveals a stronger causal relationship between technology and trade than Cambodia. Vietnam has 16 high-tech industries appearing in the quadrant with both trade and technological advantages. Among them, four high-tech ones are path-dependent trade and technological advantages. They include Rotating electric plant & parts (716), Photographic apparatus & equipment (881), Motorcycles and bicycles (785), Equipment for distributing electricity (773). In addition, six high-tech ones emerge from the quadrant without both advantages in the first period. They include two electronics, one other HT, and three engineering products. The other six high-tech sectors, include four electronics, two medium-tech ones, emerge from the quadrant without the technological advantage in the first period.

Vietnam demonstrates 24 high-tech industries with trade advantage in the first period. Six are path-dependent trade and technological advantages; one moves to the quadrant with technological advantage. In addition, four are path-dependent trade advantage. In the second period, nine high-tech ones emerge with trade advantage. They include one other HT and three process sectors, emerging from the quadrant without trade advantage, and five engineering industries are path-dependent trade advantage. Vietnam shows four high-tech industries with technological advantages in the second period. One electronics industry emerges from the quadrant with trade advantage, and three medium-tech industries emerge from the quadrant without both advantages.

Implications can be drawn from the above analysis of relationships between trade and technological specializations at the industry level by applying the movement of industries shown in figure 6.4.4.2.2. The movement (1) represents the learning by doing method that firms in most industries usually apply to develop both trade and technological advantages from the industries with trade specialization in the first period. Movement (2) or (3) represents the technology push which government tends to invest in technology in the first place to develop both trade and technological advantages or trade advantage, respectively. The government can also select the priority industries with no competitive advantages in the first period and try to gain both trade and technological advantages in movement (4). Finally, in movement (5), the government wants to develop the trade specialization applying learning by doing at the initial stage.

Figure 6.4.4.2.2 Movement of Industries



Source: Uchida et al., 2005

In Cambodia, no high-tech industry goes along with movement (1). This result is different from other East Asian countries, which shows dominant electronics industries moving along this movement among other industries (Uchida et al. 2005). The electronics industry may succeed by applying the learning by doing for a period, addressed by gaining the trade specialization without the technological specialization, before achieving both advantages. Besides, no high-tech industries move along movement (2) and (3), representing the limited pure technology push strategy. The absence of high-tech industries through these movements may be due to the lack of initiatives to support Cambodia's trade or technological advantage. Movement (4) applies to two medium-tech industries, including Motorcycles and bicycles (785) and Equipment for distributing electricity (773). These industries may be developed by multinational firms' activities, improving both trade and technological advantages.

Finally, movement (5) is the common characteristic of developing economies to expand their industries. There are 14 emerging high-tech industries in Cambodia, moving from the lower left quadrant without both advantages to the upper left quadrant with trade advantage through the arrow (5). Those industries include five electronics, four process, and five engineering industries. The five electronics sectors include Rotating electric plant and parts (716), Automatic data processing machines (752), Parts and accessories for machines (759), Electric power machinery (771), Cathode valves and tubes (776). Also, four process ones include Other man-made fibers suitable for spinning (267), Alcohols (512), Carboxylic acids (513), Other plastics (575), Tubes, pipes and hollow profiles, fittings, iron, and steel (679). The six medium-tech in engineering industries, namely Pumps, gas compressors, and fans (743), Ball or roller bearings (746), Sound recorders or reproducers (763), Apparatus for electrical circuits (772), Lighting fixtures and fittings (813). Cambodia can achieve initial success in these industries through learning by doing approach from the linkage between multinational firms and domestic firms to improve trade specialization. However, it is uncertain whether this trade specialization will enhance technological specialization in the future.

Compared with neighboring countries, Cambodia appears to have insufficient public support to promote high-tech sectors. Thailand has two high-tech industries, such as Motor vehicles for the transport of persons (781) and Optical instruments & apparatus (871), which move along the movement (1). With the movement (2), Thailand has two high-tech industries, namely Carboxylic acids, anhydrides, and halides (513) and Internal combustion piston engines and parts (71), representing the pure technology push strategy. The high-tech industries along the movement (4) include Office machines (751), Television receivers (761), Soaps, cleaning and polishing preparations (554), Tractors (722), Textile & leather machinery (724), Ships, boats & floating structures (793), representing the application of learning by doing.

Vietnam has better national science and technology infrastructure to support high-tech sectors compared to Cambodia. Vietnam has six high-tech industries going along movement (1). They include Automatic data processing machines (752), Parts and accessories for machines (759), Telecommunication equipment (764), Electric power machinery and parts (771), Waste, parings, and scrap of plastics (579), Sanitary, plumbing, heating fixtures, fittings (812). This movement represents the standard application of learning by doing in developing countries to develop their industries. Vietnam has six high-tech sectors moving through the arrow (4), suggesting the increasing presence of multinational firms interacting with domestic firms to create both trade and technological advantages. Those sectors include Office machines (751), Television receivers (761), Optical instruments & apparatus (871), Other non-electrical machinery, tools & mechanic apparatus (745), Sound recorders (763), and Meters & counters (873).

Along with the movement (5), it has five high-tech industries, including Aircraft & associated equipment (792), Ingots, primary forms of iron or steel (672), Appliances for pipes, boiler shells, tanks, vats, etc. (747), Radio-broadcast receivers (762), and Ships, boats & floating structures (793). These industries are mostly the assembly-type of production operated by subsidiaries of multinational firms. The domestic firms connect with these firms applying the approach of learning by doing to learn new knowledge and technologies related to the production processes to produce new products matching with the international standards.

In summary, Cambodia lacks the science and technology system to support the innovative performance of firms. It relies on the industrial clusters in special economic zones (SEZs) as the opportunities for domestic firms to learn new knowledge and technologies in the high-tech sectors. Cambodia has developed the SEZs along with the borders with Thailand and Vietnam and the various economic poles such as Phnom Penh, the capital city, and Sihanoukville, the seaport city. These SEZs can attract multinational firms investing in high-tech sectors from these countries or from other ASEAN countries to relocate into these SEZs. Therefore, domestic firms located in the zones can learn new knowledge and technologies from them.

On the other hand, Cambodia may rely on the interaction between domestic firms and multinational firms' subsidiaries rather than on the universities and R&D institutes to learn new knowledge and technologies. According to Chesnais (1988), Cambodia can incentivize the innovative local firms to cooperate with multinational firms to source new knowledge and technologies. There are many forms of collaboration, including university-based cooperative research projects, government-industry collaborative research projects, research corporations on a private joint venture basis, and corporate venture capital in small high-tech firms. They also include non-equity cooperative R&D agreements; technical agreements between firms in completed technology; industrial joint venture firms; comprehensive R&D, manufacturing, and marketing consortia; and one-way licensing and marketing agreements. However, the large and advanced firms apply these forms of cooperation to exchange their vital and complementary technologies, which can become the entry barriers for developing countries like Cambodia to enter the industries with the core technologies. With even more such challenges, the firms and government need a higher capability to recognize and learn those core technologies which stay at the heart of the technology systems.

Jorge Katz, who follows the Schumpeterian economics, suggests that indigenous technological capabilities still play an essential role in helping latecomers like Cambodia to catch up. According to Lee (2013), Cambodia should focus on the relationship between the knowledge regimes of sectors and the possibility of catching up. The knowledge regimes include cycle time of technology, knowledge tacitness, modularity, and embodied technology transfer. These knowledge regimes are divided into two categories. First, the access to foreign technological knowledge bases includes embodied technology transfer and modularity. Second, the elements related to learning possibility include knowledge tacitness and cycle time of technology. Latecomer firms with high organizational and technological capabilities can access foreign technological knowledge bases to learn new knowledge and technologies to develop new products and processes required to compete successfully in the international market.

6.5 Conclusion

Cambodia has widened its specialization pattern slightly with the slow mobility within and between sectors over an extended period, particularly with more pronounced in high-tech industries. However, it starts to concentrate on the new sectors in the last two periods. Cambodia starts to diversify its technological specialization patterns in the long run for high-tech industries, even though it starts to concentrate on the newly established sectors in the last two periods. Cambodian high-tech industries show stickiness and incremental change, which means that the initial less specialized industries move slowly to the average; meanwhile, the initial high specialized industries move back to the average within industries. They also reveal the slow mobility between sectors toward the sectors with a broad pattern of specialization.

For high-tech industries, Cambodia shows that technology influences trade in the first period and vice versa for the last two periods. This relationship suggests the abundance of high-skilled workers during the first period, attracting domestic and foreign firms to invest in the high-tech industries. For the last two periods, Cambodia has developed the high-tech industries by applying the learning by doing method, which is common in developing countries that always try to use it to build their priority sectors at the early stage. The slow movement between industries in the last two periods may result from the lack of long-term oriented entrepreneurs with adequate organizational and technological capabilities to accelerate the movement speed between sectors toward the more narrow specialized high-tech industries. This finding supports the claim that Cambodia's science and technology system is emergent, which cannot upgrade and mobilize the critical mass of the nationalistic and long-term entrepreneurs to contribute to the industrial transformation.

The implications of the movement of industries show that no high-tech industry moves from a quadrant with trade advantage to a quadrant with both trade and technological advantages. However, Thailand obtained two high-tech industries, and Vietnam obtained six high-tech ones. Cambodia lacks FDIs in high-tech ones with path-dependent trade advantages to support domestic firms by applying the learning by doing approach to learn new knowledge and technologies for a period before transforming these industries to obtain both trade and technological advantages. There is no high-tech industry moving from the quadrant with technology advantage to quadrant with trade advantage or quadrant with both advantages. This result implies that Cambodia has not yet applied the technology push strategy to support the domestic firms to upgrade their organizational and technological capabilities in the high-tech and medium-tech industries.

Only two medium-tech industries, namely Motorcycles and bicycles (785) and Equipment for distributing electricity (773), move from the quadrant without trade and technological advantages to the quadrant with both of them. These industries' success may be due to the linkage between multinational firms and domestic firms located in the SEZs applying the learning by doing approach by which the latter can learn new knowledge and technologies from the former. Fourteen high-tech industries move from the quadrant without any advantage to the quadrant with trade advantage. They include five electronics, four process, and five engineering industries. These industries' success may derive from the interaction between multinational firms and the domestic firms operating the business within the assembly-type of products. Domestic firms can learn from multinational firms by applying the method of learning by doing through different forms of cooperation. This finding suggests that there are many medium-tech and high-tech industries, which require adequate science and technology infrastructure to support their innovation and diffusion in the Cambodian economy.

Sectoral innovation policies should be adopted to upgrade the sectoral innovation systems to support the specific sectors, including two growing medium-tech sectors in automotive and engineering, five emerging electronics, four emerging process, and five emerging engineering sectors.

Chapter 7: Concluding Remarks and Policy Suggestions

7.1 Concluding Remarks

Cambodia is characterized as an emergent innovation system in which management capabilities and citizens' competencies are the central units of the NIS analysis (Chapter 3). This characteristic is in line with the result of the empirical studies of Chapter 4 Chapter 5 and Chapter 6. Even though the business environment is improved in general, it is still not conducive to firms' innovation efforts because they still lack finance, lack skilled labor, and confront international trade obstacles. However, government capability seems to be improved since government regulations and telecommunications tend to support R&D activities. The competitive environment is seen to be favorable for promoting innovation activities and product innovation.

According to the literature review in Chapter 3, management capabilities are still low due to the limited management extension services. As seen in Chapter 4, the technological cooperation indicator shows the weak linkage between firms and public institutions, suggesting that they have limited management capabilities. There is another kind of interpretation. R&D activities have a significant impact on innovation outcomes, but only product innovation has a small significant impact on labor productivity, suggesting that Cambodian firms' management capabilities are still limited. The limited management capabilities may lead firms to invest in a low level of R&D activities since the former is the main complementarity factor to the latter (Chapter 3 and Chapter 4).

On the other hand, the complementarity factors to R&D include internationally-recognized certification, foreign technology license, physical capital, and human capital. Cambodian firms have slowly accumulated these factors because the general business environment is still burdensome, suggesting the reason to explain the low level of R&D activities. Chapter 3 also indicates similar reasoning. The low level of these two capabilities may also result from the lack of skilled workers and financing such as risk capital and innovative financial services.

Cambodian export structure is characterized as "missing the middle" since it has a limited number of medium-sized exporters, local suppliers, and tech SMEs. According to Chapter 3, this small number of medium-sized exporters derive from high exporting costs, limited national qualification infrastructure, burdensome business regulations, limited management capabilities, and R&D activities. The tech startup ecosystem is incipient that it cannot help upgrade the tech SMEs by supporting through their firm life cycle to transform them to become global firms. Domestic suppliers also have limited firm capabilities in management and technological capabilities, making the linkage between them and multinational firms located in the SEZs is still weak. Thus, it is difficult for Cambodia to develop supporting industries to supply parts and components to multinational firms or export to international markets.

This finding is similar to Chapter 5 and 6, showing the limited capacity of science and technology systems to support SMEs to upgrade their organizational and technological capabilities because Cambodia shows slow mobility within sectors toward the average and between sectors toward the broad pattern of specialization. As a result, Cambodia lacks the critical mass of Schumpeterian entrepreneurs who can cooperate with multinational companies and succeed in supplying parts and components to MNCs or exporting to international markets. Thus, upgrading the management capabilities will make the demand for conducting R&D activities of the domestic firms increase. When these two capabilities are strengthened and accompanied by improving access to finance, access to skilled labor, and reducing trade costs through trade facilitation, the number of medium-sized exporters, domestic suppliers, and tech SMEs will increase.

The university-industry linkage is still weak in Cambodia. This weak linkage may derive from the low level of the management capabilities of the firms and the universities or research institutions and the lack of collaboration mechanisms, such as innovation vouchers, research grants, and tax incentives system to promote cooperation. Apparently, 7% of sample firms apply technological collaboration to interact with other firms or public institutions to introduce process innovation. In the same vein, 14% of them apply subcontracting to interact with exporting firms to introduce product and organization innovations. In addition, 27% and 56% of sample firms interact with clients and suppliers using website and email to introduce product innovation, respectively.

Cambodia's national science and technology system is less-developed to support firm capability upgrading in the high-tech sector because its economic structure is transformed into high-tech sectors slower than neighboring countries (Chapter 5 and 6). Cambodia is transforming its economic structure into higher value-added sectors such as electronics, automotive, process, engineering, LT products other than garment, and resource-based sectors. However, it still relies on the garment and agriculture sectors. Cambodia has four growing industries, 16 emerging industries, 11 marginal industries, and 23 losing industries in terms of trade specialization of high-tech industries. On the other hand, in terms of trade specialization of low-tech industries, it has 11 growing industries, 12 emerging industries, 71 marginal industries, and 11 losing industries. High-tech industries should become candidates for industrial promotion strategies since developing them can accelerate structural transformation (Hausman et al., 2006; Freeman et al., 1988). Only two high-tech industries move from the quadrant without trade advantage and technological advantage to the quadrant with both of them. Fourteen high-tech industries move from the quadrant without both advantages to the quadrant with trade advantage. They include five electronics, four process, and five engineering industries. This implication suggests that Cambodia attracts multinational firms, operating their businesses as an assembly-type production in the high-tech industries. They may interact with domestic firms through different forms of cooperation by applying learning by doing.

The Cambodian SEZs have been recognized as a policy tool to attract FDIs in new high-tech industries to locate inside them (Chapter 3). They should be developed as industrial clusters, which can be used as policy tools since they can provide the five agglomeration advantages to upgrade the organizational and technological capabilities for the domestic firms locating in the zones (Caniels et al., 2004). The five agglomeration advantages include the economy of scale, scope, and transactions in production; the economy of scale, scope, and transactions of knowledge production; knowledge spillovers through changing the attitude and motivation; knowledge spillovers through human capital formation and informal learning by doing; knowledge spillovers through technology transfer.

Through these advantages, Cambodian firms can afford the cost-saving to invest in innovation activities. They also obtain lower transaction costs due to the increasing presence of specialized suppliers. The low transaction costs also facilitate the joint undertaking of technological efforts to make cost-saving and stimulate the additional technological effort in complementary projects. The technology spillovers can be obtained through demonstration effect to promote changing attitude and motivation and through human capital formation and informal 'learning by doing' by receiving the direct free inputs from the industry-wide accumulation of skills. Finally, technology spillovers can be obtained by accessing direct free inputs through well-trained labor, user-producer interaction, and trade journals, meetings, and fairs.

7.2 Policy Suggestions

Based on the implications found in this study, we suggest the following selective innovation policies and their implementation:

- Informal firms are dominant in Cambodia. Thus, it should continue to modernize and implement online business registration effectively to facilitate business registration procedures and reduce corruption. It should continue to implement the targeted business registration and tax incentives system in a broader scope to increase the Cambodian economic structure's formality for an even deeper level. The business regulations should be enhanced since the informal firms perceive them as lower constraints than the formal ones that encourage them to stay informal. They include business licensing and operating permits, customs and trade regulations, regulatory policy uncertainty, tax rates and tax administration, corruption, business conflicting and resettlements, and anti-competitive and informal practices. The formality of firms can facilitate implementing the government's targeted SME development policy to develop SMEs' firm capabilities.

- Thailand has achieved its industrial transformation into dominant automotive industries and electronics, process, and engineering industries to a lesser extent, while Vietnam transform itself into electronics. Thus, Cambodia needs to upgrade further the multi-modality transport infrastructure and soft infrastructure to link its economic poles in Phnom Penh, Sihanoukville, and the borders to the two big industrial centers in Bangkok (Thailand) and Ho Chi Minh (Vietnam). This development helps reduce the importing and exporting costs, attracting foreign firms to invest in Cambodian SEZs near the borders or inside the country and encourage domestic firms to locate inside them. This international integration can increase the speed of both trade and technological specialization in the high-tech industries if Cambodia provides appropriate science and technology system to support domestic firms located in the SEZs, in which there are many large domestic and foreign firms inside.
- The Royal Government of Cambodia (RGC) has already adopted the SME development policy, but its implementation is still ineffective. The RGC could coordinate this new policy with the Industrial Development Policy 2015-2025 and strengthen its implementation capacity by improving the National Productivity Center of Cambodia (NPCC) to help build existing SMEs' firm capabilities to a larger extent. The NPCC can be enhanced by cooperating with famous international agencies such as Japan Productivity Center to learn and build management extension services skills while it is operating to support the private sectors. The productivity movement should be brought into the media to promote public agencies and private firms to invest in upgrading their management capabilities, like what Singapore used to do. It should validate the Entrepreneurship Promotion Center (EPC) as SPRING in Singapore. The EPC can help support new SMEs in building management competence and technological capability and provide the financial support for them. This support should be provided through their firm life cycle from conception in the early stage to the growth stage before they become global firms. Simultaneously, the Incubation and Acceleration Centers should also be created to support the early stage and growth stage of the firm life cycle. On the other hand, the supplier development programs that used to be applied by the Ministry of Commerce should be enhanced to develop the firm capabilities of the domestic suppliers. With these substantial public supports, the number of medium-sized exporters and qualified domestic suppliers will increase. These domestic firms will increase the in-house R&D activities which need to be supported by the national innovation agencies.
- Cambodia is diversifying its economic structure into high-tech industries; however, the movement is slow. Thus, it needs to construct the science and technology system to support the innovative and growth SMEs to upgrade their organizational and technological capabilities to absorb and adopt new technologies to move up the regional and global value chains in the high-tech industries. Cambodia has the proportion of high-growth SMEs at about 40% of the sample firms (World Bank, 2018), which may need the support of R&D activities from public R&D institutes, technology extension centers, and universities. RGC should redesign and upgrade these government agencies by providing different incentives and reward system to mobilize technicians, engineers, and scientists to work in these

institutions. The R&D institutes include the National Productivity Center of Cambodia (NPCC), the Industrial Laboratory Center of Cambodia (ILCC), the Technology Incubation Center (TIC), the Royal Academy of Cambodia (RAC), the Institute of Science and Technology (OECD, 2013). There are seven most prestigious public universities, such as the Royal University of Phnom Penh (RUPP), the Institute of Technology of Cambodia, the Royal University of Agriculture, the Royal University of Fine Arts, the National University of Management, the Royal University of Law and Economics, the Royal University of Health Sciences, and the National University of Battambang. These public universities have the potentials to produce scientific knowledge and to supply qualified technicians, engineers, scientists, and entrepreneurs, contributing to upgrading firm capabilities if the government directs them to do so.

- To increase SME support scale, the RGC needs to promote and strengthen SME bank's role to provide the risk capital options and innovative financial services while trying to convince the traditional banking system to provide the same benefits to SMEs. The innovative financial services include cryptocurrency using blockchain technology, crowdfunding sources of investments, peer-to-peer lending, angel investment, and venture capital, which play a role in supporting startups and tech SMEs. The SME bank should continue to support the potential growth SMEs by providing SME co-financing services. The SME co-financing service is the loan arrangements obtained from an equal match of funds between SME bank and commercial banks or microfinance institutions with subsidized interest rate. This service is created to support domestic firms during and after the Covid-19 pandemic crisis to prevent domestic firms from closing their businesses. Also, the Guarantee Scheme Corporation of Cambodia needs to develop loan guarantee schemes and continue to support domestic firms to receive long-term loans from commercial banks or microfinance institutions. Thus, they have adequate long-term financial resources to invest in long-term innovation projects. RGC could also continue implementing match-granting, which is the match of the equal amount of fund between the public fund and SMEs, to support SMEs' actual expenditures in R&D activities and digital technological adoptions.
- Cambodia needs to develop the basic national quality infrastructure (NQI) since domestic firms need to adapt their products and processes to international standards. The Institute of Standards of Cambodia (ICS) plays the role of developing or adopting the international standards and diffuse them to domestic firms to improve the standards of their products and processes to meet domestic and international market needs. The Industrial Laboratory Center of Cambodia should improve its quality and enlarge its operations to meet Cambodian firms' demand for product testing and certification.
- The RGC should orientate the famous public universities mentioned above and other potential universities to become research universities to develop adequate qualified technicians, engineers, and scientists to work in the public agencies and private sector. These universities can attract qualified diaspora and qualified researchers to balance between research and teaching skills in their institutions through the incentives and reward system. It also needs to consider allocating funds to provide the scholarship for fresh graduates to continue their master's degree and Ph.D. degree in advanced countries and work in public agencies while they return. At the same time, these universities should

create new international master's degree and Ph.D. degree programs by collaborating with the partner universities in the advanced countries to upgrade the current lecturers and new students to balance the teaching staff's two skills in their institutions. Cambodia needs to build a new workforce and upgrade the existing one. To achieve this goal, the RGC needs to strengthen the implementation of the existing technical and vocational education training policy and education policy by upgrading the capacity of the training centers and technical high schools while providing the training of trainers programs to upgrade the lecturers' capacity to implement the curriculum successfully. The RGC should consider adopting the grant levy system, implemented successfully in South Korea, Singapore, and Malaysia, to promote domestic and foreign firms to provide the training programs to upgrade their existing workforce.

- The RGC should consider to adopt the University-Industry Linkage Approach to promote the interaction between higher education institutions and industries to develop curricula that adapt to the labor market requirement. They can also apply this collaboration mechanism to forecast future skills needs in industry 4.0, so the training providers can develop their students' skills right to the future labor market demand in industry 4.0. The RGC should consider adopting the incentives system to support the collaboration among innovation actors, such as innovation vouchers, research grants, and R&D tax incentives, to promote cooperation between firms and between firms and technology extension centers, R&D institutes, and universities. Even though the Cambodian innovation system's demand side is still small, Cambodia needs to develop these mechanisms to promote this interaction to upgrade its innovation system to become a mature one. On the other hand, the R&D system that can support the success of the R&D activities of the domestic firms needs a long period to build, so Cambodia must start it at the early stage of the capabilities escalator with the amount in needs from the private sector.
- The RGC should also consider adopting sectoral innovation policies to support the growing and emerging high-tech sectors and some of the marginal and losing industries found in Chapter 5 and 6. Cambodia has good experience in adopting and successfully implementing the rice policy 2010. Since SEZs have a high proportion of multinational firms (Chapter 3), it can attract the local SMEs to locate in the SEZs and help upgrade their firm capabilities by providing export market information and matchmaking services to support them. It also needs to adopt and implement supplier development programs to upgrade local SMEs' organizational and technological capabilities to move from captive and hierarchical forms to modular and relational forms, which can help elevate them to become global firms. However, these public interventions should be implemented and assessed by sectors since each sector needs complementary knowledge and technologies, which allow it to succeed. According to Caniels et al. (2004), Cambodia needs to adopt sectoral innovation policies to focus on three different ways to promote industrial competitiveness. First, the object of policy should be set to stimulate the dynamic technological learning by positioning the clustered firms in the GVCs to choose the appropriate governance form of GVC for providing the support to upgrade the specific firm capabilities. Second, the geographical coverage should be concentrated on the industrial clusters rather than on industries in general since agglomeration effects help leverage firms' technological capabilities in the industrial clusters. Third, a small number

of progressive firms should be selected as a target for the implementation to diffuse the broader impact, so resources can be reserved to increase the scope of interventions to promote industrial specialization even further.

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Appendix

Table A.4.1 A Non-Parametric Test

Variables	R&D Decision (1)	R&D Intensity (2)	Innovation Investment Decision (3)	Innovation Investment Intensity (4)
Medium	-.0301 (.2556)	-.1134 (.4254)	-.1638 (.1814)	-.2009 (1.4061)
Large	.4365 (.3700)	-1.0441 (.8420)	.2559 (.2697)	.1573 (2.2193)
Foreign Owned	-.4195 (.4805)	-.1688 (.9407)	-.2439 (.3399)	.2352 (2.3640)
Importer	-.1453 (.5028)	.5862 (.8259)	-.1554 (.3466)	-1.0307 (1.6232)
Exporter	.0374 (.3837)	.2757 (.6694)	-.0843 (.2864)	-.6663 (1.1211)
Two-Way Trader	.3256 (.6754)	.8295 (1.2263)	-.1509 (.4989)	-.6034 (1.8553)
Demand Increasing	-.2510 (.2166)	.2571 (.5401)	.2200 (.1673)	.1186 (1.8696)
Market Share	-86.7046 (117.6574)	1.0760 (5.3276)	12.1934 (21.5473)	19.9579 (35.1982)
Extent of Informal Competition	.1485* (.0897)	.0004 (.2415)	.1233* (.0636)	.0582 (.9939)
Certification	.4371 (.4384)	.9381 (1.0511)	.5560 (.3379)	.5442 (4.5219)
Technology License	.3600 (.3624)	-.0809 (.7896)		
New Capital	.9110*** (.2251)	.3560 (1.2758)		
Lack of Finance	-.1916 (.1207)	-.0550 (.3046)	-.2309*** (.0882)	-.1386 (1.8599)
Trade Costs Obstacle	-.3669** (.1770)	.0259 (.5373)	-.0641 (.1306)	.1378 (.6475)
Telecommunication Obstacle	.0742 (.1208)	.2697 (.2281)	.0382 (.0867)	-.0318 (.4112)
Government Obstacle	.3616* (.1992)	.24966 (.5837)	.0925 (.1471)	-.3797 (.8425)
Predicted Probability of R&D		358.7787 (496.7352)		-5825.604 (7510.94)
Square of Predicted Probalility of R&D		-254.1156 (346.9234)		-5825.604 (7510.94)
Mill Ratio				
Square of Mill Ratio				-19428.89 (24529.63)
Interaction Term		-442.9828 (643.4868)		-17395.95 21780.91
Constant	-1.5227*** (.3165)	-.8630 (1.2058)		12367.68 (15613.17)
Observation	328	328	223	223
ISIC-2 digit dummy	Yes	Yes	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.2 Innovation Input Equation Using GSEM for Sensitivity Analysis

Variables	R&D Intensity (1)	Innovation Investment Intensity (2)
Medium	-.1848 (.3640)	-.3852 (.4898)
Large	-.4603 (.5428)	.7462 (.7262)
Foreign Owned	-.5424 (.6736)	-.2008 (.9074)
Importer	.4312 (.6707)	-1.1671 (.9049)
Exporter	.3105 (.5835)	-.6419 (.7899)
Two-Way Trader	1.2771 (1.0328)	-.8508 (1.3909)
Demand Increasing	-.0852 (.3324)	.4785 (.4455)
Market Share	-2.056 (3.6399)	5.0912 (4.9021)
Extent of Informal Competition	.1452 (.1270)	.2464 (.1743)
Certification	1.4213* (.7470)	2.0330** (1.0070)
Technology License	.3163 (.5737)	5.5907 (.7740)
New Capital	1.7275*** (.3306)	
Lack of Finance	-.2455 (.1557)	-.3797 (.2360)
Trade Costs Obstacle	-.3342 (.2326)	-.0678 (.2737)
Telecommunication Obstacle	.3038 (.1673)	.1270 (.1910)
Government Obstacle	.4479 (.2883)	-.2244 (.2673)
Constant	.0365 (.4807)	2.0894*** (.6196)
Observation	373	373
ISIC-2 digit dummy	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.3 Innovation Output Function Using GSEM for Sensitivity Analysis

Variables	Trivariate Probit			Trivariate Probit		
	Prod_Inn	Proc_Inn	Org_Inn	Prod_Inn	Proc_Inn	Org_Inn
Predicted R&D Intensity	-.0198 (.1063)	.2402*** (.0599)	-.1490* (.0779)			
Predicted Innovation Investment Intensity				-.0156 (.2333)	-.0872 (.1666)	-.2049*** (.0554)

Technological Cooperation	.2351 (.2570)	1.2450 (.2945)	-.3151 (.2369)	.1826 (.2430)	1.5230*** (.4049)	-.1963 (.1853)
Subcontract	.4744 (.4333)	-.0591 (.3299)	.9132*** (.3069)	.4072 (.4280)	-.0270 (.3622)	.6174 (.3405)
Email	.4642** (.2057)	-.3014* (.1776)	-.0111 (.1615)	.4735** (.2059)	-.3417* (.2008)	-.0306 (.1069)
Website	.5534*** (.2032)	.1495 (.1785)	.1131 (.1538)	.5611*** (.2025)	.0696 (.1934)	.0705 (.1057)
Medium	-.3721* (.2115)	.0835 (.1799)	.1167 (.1834)	-.3758* (.2215)	.0195 (.2040)	.0381 (.1663)
Large	-.1717 (.3036)	.0625 (.2830)	1.2520*** (.3454)	-.1457 (.3471)	.0414 (.3155)	1.0392** (.4463)
Foreign owned	.8039** (.3667)	-.0219 (.3227)	-.0648 (.2717)	.7835** (.3630)	-.0995 (.3355)	-.0452 (.2500)
Importer	.1854 (.4105)	-.2482 (.3538)	1.2131*** (.3846)	.14065 (.4755)	-.2357 (.3862)	.5040 (.5047)
Exporter	.2547 (.3522)	.1964 (.3052)	-.1036 (.3003)	.2742 (.3950)	.1117 (.3618)	-.2357 (.2541)
Two-way-trader	-.6941 (.6965)	.2708 (.5346)	.6110 (.5771)	-.7298 (.7126)	.5852 (.6365)	-.0032 (.5119)
Demand Increasing	.5434*** (.1938)	-.0034 (.1590)	-.0434 (.1592)	.5558** (.2197)	-.0360 (.1865)	.1145 (.1410)
Market Share	-3.8419 (28.2638)	-37.9882 (28.8320)	-1.5751 (2.0724)	-2.2435 (11.4968)	-46.2935 (32.1053)	.01350 (1.8005)
Extent of Informal Competition	.2396*** (.0657)	-.0067 (.0565)	.0978* (.0553)	.2410*** (.0702)	.0395 (.0601)	.0730 (.0498)
Certification	.6247 (.4391)	.0472 (.3664)	.5037* (.3049)	.6137 (.6397)	.6514 (.4311)	.5881** (.2804)
Foreign Technology Use	.0567 (.3050)	.3783 (.2644)	.6674** (.2698)	.1450 (1.3260)	.8947 (.8529)	1.5660*** (.2498)
Capital Intensity	.0622 (.0466)	.0320 (.0336)	-.0500 (.0339)	.0629 (.0465)	.0347 (.0367)	-.0299 (.0271)
Educated Labor Force	.0416 (.0762)	-.0795 (.0633)	-.0599 (.0614)	.0404 (.0777)	-.0778 (.0679)	-.0432 (.0453)
Training Decision	.7698*** (.1847)	-.0472 (.1597)	.5334 (.1623)	.7730*** (.1831)	-.0387 (.1736)	.3428* (.1919)
Constant	-2.8720*** (.7831)	-1.0868* (.5587)	-.6129 (.5963)	-2.8750*** (.8576)	-.8682 (.7617)	-.2023 (.5111)
Observation	373	373	373	373	373	373
ISIC-2 digit dummy	Yes	Yes	Yes	Yes	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.4 Productivity Function Using GSEM for Sensitivity Analysis

Variables	Sales per Worker (R&D Intensity)	Sales per Worker (Innovation Investment Intensity)
Capital Intensity	.0756* (.0417)	.0766* (.0422)
Firm Size	.2034** (.0789)	.2153*** (.0789)
Predicted Product	.8961*	.8620*

Innovation	(.4858)	(.4926)
Predicted Process Innovation	-.2679 (.4747)	-.1797 (.4571)
Predicted Organizational Innovation	-2.3857*** (.3837)	-2.5065 (.4037)
Constant	16.0782*** (.7126)	16.0340*** (.7133)
Observation	373	373
ISIC-2 digit dummy	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.5 Innovation Input Equation Using IV Estimation

Variables	R&D Intensity	Innovation Investment Intensity
Medium	-.1946 (.3836)	-.3852 (.5166)
Large	-.4600 (.5777)	.8017 (.7798)
Foreign Owned	-.5741 (.7125)	-.3012 (.9615)
Importer	.4561 (.7070)	-1.1568 (.9530)
Exporter	.2977 (.6156)	-.6154 (.8309)
Two-Way Trader	1.2812 (1.0812)	-.8880 (1.4567)
Demand Increasing	-.0848 (.3504)	.4466 (.4690)
Market Share	-2.1684 (3.8360)	4.9483 (5.1643)
Extent of Informal Competition	.1494 (.1363)	.2826 (.1832)
Certification	1.3763* (.7870)	2.0340* (1.0624)
Technology License	.3017 (.6048)	5.5653*** (.8148)
New Capital	1.6304*** (.3616)	
Lack of Finance	-.2589 (.1755)	-.4554 (.2370)
Trade Costs Obstacle	-.4347 (.2634)	-.0098 (.3555)
Telecommunication Obstacle	.3223* (.1857)	-.0294 (.2507)
Government Obstacle	.6875** (.3124)	-.1316 (.4212)
Constant	-.0750 (.5102)	2.0526*** (.6680)
Observation	373	373
ISIC-2 digit dummy	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.6 Innovation Output Function Using IV Estimation

Variables	Prod_Inn	Proc_Inn	Org_Inn	Prod_Inn	Proc_Inn	Org_Inn
	(Using R&D Intensity)			(Using Innovation Investment Intensity)		
Predicted R&D Intensity	.0937 (.0818)	.2514*** (.0798)	-.0033 (.0918)			
Predicted Innovation Investment Intensity				.0503 (.0446)	.0706 (.0444)	.0916* (.0493)
Technological Cooperation	.0828 (.2298)	1.3893*** (.2223)	-.3515 (.2730)	.1432 (.2234)	1.4843*** (.2169)	-.3426 (.2724)
Subcontract	.4506 (.3257)	.1191 (.3158)	.8407*** (.3189)	.5145 (.3267)	.2366 (.3141)	.8914*** (.3192)
Email	.3910** (.1908)	-.2752 (.1894)	.1648 (.2193)	.4006** (.1911)	-.2526 (.1874)	.1515 (.2211)
Website	.5815*** (.1941)	.0797 (.1990)	.1777 (.2094)	.5660*** (.1946)	.0271 (.1978)	.1610 (.2108)
Medium	-.3260* (.1974)	.1321 (.1866)	.2846591 (.214095)	-.3200747 (.1980798)	.11204 (.1861184)	.3601666 (.2197859)
Large	-.234865 (.2867224)	.0007 (.2896)	1.1470*** (.2991)	-.2940 (.2809)	-.1531 (.2782)	1.1883*** (.2945)
Capital Intensity	.0589 (.0423)	.0458 (.0372)	-.0163 (.0419)	.0510 (.0414)	.0290 (.0366)	-.0223 (.0421)
Educated Labor Force	.0668 (.0716)	-.0546 (.0697)	.0077 (.0791)	.0742 (.0709)	-.0327 (.0683)	.0039 (.0793)
Training Decision	.8295*** (.1745)	-.0386 (.1785)	.6602*** (.1863)	.8255*** (.1748)	-.0261 (.1773)	.6483*** (.1872)
Constant	-2.0606*** (.6972)	-1.4018** (.6081)	-1.3662** (.6868)	-2.0198*** (.6801)	-1.1710** (.5927)	-1.5334** (.6901)
Observation	354	363	351	354	363	351
ISIC-2 digit dummy	Yes	Yes	Yes	Yes	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.7 Productivity Function Using IV estimation

Variables	Sales per Worker (R&D Intensity)	Sales per Worker (Innovation Investment Intensity)
Capital Intensity	.0429 (.0403)	.0431 (.0403)
Firm Size	.1551* (.0916)	.1385 (.0892)
Predicted Product Innovation	1.6660** (.6583)	1.6379** (.6498)
Predicted Process Innovation	-.4555 (.4394)	-.2006 (.4495)
Predicted Organizational Innovation	-2.2165*** (.8401)	-1.980693** (.7864)
Constant	16.4969*** (.6733)	16.0428*** (.6499)
Observation	373	373
ISIC-2 digit dummy	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.8 Innovation Input Equation Using SEM

Variables	R&D Intensity (Bivariate)	R&D Intensity (Trivariate)	Innovation Investment Intensity (Bivariate)	Innovation Investment Intensity (Trivariate)
Medium	-.1974 (.3671)	-.2671 (.3667)	-.4406 (.4955)	-.4804 (.4957)
Large	-.4977 (.5231)	-.4616 (.5315)	.6396 (.7394)	.7088 (.7366)
Foreign Owned	.4867 (.4366)	.2006 (.5717)	.5440 (.8662)	.2683 (.8500)
Importer	.4367 (.4388)	.6655 (.5789)	-.7536 (.8581)	-.2026 (.8965)
Exporter	.5719 (.3996)	.5239 (.4621)	-.1355 (.7477)	-.2819 (.7235)
Two-Way Trader	.1357 (.7397)	.6775 (.8481)	-1.0173 (1.2800)	-.5392 (1.2616)
Demand Increasing	.3827* (.2131)	.2884 (.2784)	.7854* (.4125)	.6949* (.4157)
Market Share	-1.9939 (2.3635)	-3.2457 (2.8025)	2.9062 (4.4591)	1.1375 (4.4806)
Extent of Informal Competition	.2999*** (.0934)	.2955*** (.1037)	.4826*** (.1640)	.4630*** (.1586)
Certification	1.2813** (.5721)	1.4889** (.6151)	2.4447*** (.9004)	2.3402*** (.8982)
Technology License	.3738 (.3925)	.7158 (.4692)	4.7647*** (1.0200)	5.0045*** (.9111)
New Capital	.7389* (.4299)	1.0570** (.4817)		
Lack of Finance	-.0719 (.1199)	-.0982 (.1389)	-.3538 (.2176)	-.3224 (.2103)
Trade Costs Obstacle	-.3130* (.1859)	-.3797* (.2019)	-.1762 (.3018)	-.2050 (.2988)
Telecommunication Obstacle	.2539* (.1323)	.2550* (.1460)	.1088 (.2170)	.0567 (.2148)
Government Obstacle	.3432** (.2356)	.5173** (.2594)	-.0377 (.3566)	.1119 (.3603)
Constant	-.3848 (.4445)	-.4701 (.4292)	1.3943** (.6259)	1.3906** (.6039)
Observation	373	373	373	373
ISIC-2 digit dummy	Yes	Yes	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.9 Innovation Output Function Using SEM

Variables	Bivariate Probit		Trivariate Probit			Bivariate Probit		Trivariate Probit		
	Prod_Inn	Proc_Inn	Prod_Inn	Proc_Inn	Org_Inn	Prod_Inn	Proc_Inn	Prod_Inn	Proc_Inn	Org_Inn
	(Using R&D Intensity)					(Using Innovation Investment Intensity)				
Predicted R&D Intensity	.1472*** (.0683)	.0750** (.0345)	.0848* (.0474)	.0940*** (.0295)	.0387 (.0287)					
Predicted Innovation Investment Intensity						.0414* (.0228)	.0249 (.0152)	.0364** (.0173)	.0270* (.0150)	.0295** (.0129)
Technological Cooperation	-.0016 (.0607)	.4759*** (.0643)	.0416 (.0613)	.4360*** (.0687)	-.1559*** (.0542)	.0265 (.0601)	.5253*** (.0639)	.0408 (.0599)	.5167*** (.0649)	-.1089** (.0540)
Subcontract	.0958 (.0960)	.0145 (.0942)	.1357 (.0879)	-.0101 (.0914)	.2048*** (.0710)	.1405 (.0918)	.0502 (.0958)	.1681** (.0824)	.0512 (.0938)	.2458*** (.0722)
Email	.0849 (.0562)	-.0521 (.0615)	.1237*** (.0470)	-.0837 (.0511)	-.0171 (.0423)	.1145** (.0568)	-.0634 (.0603)	.1391*** (.0463)	-.0862 (.0538)	-.0162 (.0414)
Website	.1534*** (.0520)	.0236 (.0555)	.1506*** (.0488)	.0321 (.0531)	.0821 (.0412)	.1522*** (.0531)	.0021 (.0566)	.1388*** (.0488)	.0098 (.0560)	.0778* (.0420)
Medium	-.0582 (.0767)	.0283 (.0559)	-.0252 (.0600)	.0097 (.0582)	.0295 (.0435)	-.0608 (.0573)	.0348 (.0562)	-.0243 (.0535)	.0181 (.0569)	.0399 (.0443)
Large	.0492 (.1180)	-.0112 (.0879)	.0324 (.0959)	-.0144 (.0889)	.3234*** (.0763)	-.0622 (.0817)	-.0394 (.0818)	-.0269 (.0830)	-.0482 (.0820)	.3074*** (.0717)
Capital Intensity	.0164* (.0093)	.0098 (.0099)	.0176* (.0094)	.0089 (.0100)	-.0044 (.0086)	.0122 (.0095)	.0086 (.0102)	.0143 (.0096)	.0078 (.0102)	-.0063 (.0086)
Educated Labor Force	.0072 (.0189)	-.0170 (.0202)	.0114 (.0172)	-.0209 (.0188)	-.0020 (.0145)	.0171 (.0190)	-.0098 (.0202)	.0173 (.0168)	-.0112 (.0197)	-.0017 (.0146)
Training Decision	.2343*** (.0478)	-.0037 (.0511)	.2249*** (.0459)	.0094 (.0491)	.1902*** (.0394)	.2437*** (.0498)	-.0111 (.0527)	.2210 (.0469)	.0046 (.0514)	.1949*** (.0392)
Constant	-.1832 (.1666)	.0888 (.1648)	-.1926 (.1591)	.1129 (.1647)	.1139 (.1413)	-.1452 (.1631)	.0953 (.1678)	-.1826 (.1596)	.1150 (.1682)	.0845 (.1414)
Observation	373	373	373	373	373	373	373	373	373	373
ISIC-2 digit dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.10 Productivity Function Using SEM

Variables	Sales per Worker (R&D Intensity) (Bivariate)	Sales per Worker (R&D Intensity) (Trivariate)	Sales per Worker (Innovation Intensity) (Bivariate)	Sales per Worker (Innovation Intensity) (Trivariate)
Capital Intensity	.0893** (.0372)	.0453 (.0602)	.0842** (.0376)	.0443 (.0545)
Firm Size	.0326 (.0696)	.1831* (.0932)	.0134 (.0687)	.1727* (.0896)
Predicted Product Innovation	-.0855 (.5236)	2.5088* (1.4009)	.3014 (.5478)	2.4844** (1.1001)
Predicted Process Innovation	.3056 (.5592)	-1.2394 (.9717)	.2675 (.4885)	-.4791 (.6669)
Predicted Organizational Innovation		-3.6415*** (1.5107)		-3.1945*** (1.1690
Constant	16.0614*** (.6458)	16.5952*** (1.0165)	16.0820*** (.6380)	16.3395*** (.8853)
Observation	373	373	373	373
ISIC-2 digit dummy	Yes	Yes	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.11 Innovation Input Equation Using IV Estimation (Thailand and Vietnam)

Variables	R&D Intensity (Thailand)	R&D Intensity (Vietnam)
Medium	.0076 (.0090)	.5014** (.2236)
Large	-.0175 (.0119)	.2722 (.2695)
Foreign Owned	-.0186 (.0167)	-.2318 (.3878)
Importer	.06673*** (.0251)	.7147* (.3893)
Exporter	.0121 (.0114)	-.0856 (.3465)
Two-Way Trader	.0374* (.0223)	.0855 (.3599)
Demand Increasing	.0017 (.0081)	.2350 (.1933)
Market Share	-1.7116 (4.5741)	43.7797*** (12.8253)
Extent of Informal Competition	.0007 (.0054)	.2533*** (.0872)
Certification	.03005*** (.0113)	1.0714*** (.2877)
Technology License	-.0044 (.0151)	.2855*** (.3918)
New Capital	.0566*** (.0145)	1.0388*** (.1997)
Lack of Finance	-.0135** (.0060)	.0674 (.0934)
Trade Costs Obstacle	-.0108 (.0075)	.2471 (.1523)
Telecommunication Obstacle	.0067 (.0045)	.0997 (.1194)
Government Obstacle	.0339*** (.0093)	.1859 (.1918)
Constant	-.0099 (.0117)	-.2624 (.3325)
Observation	1000	996
ISIC-2 digit dummy	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.12 Innovation Output Function Using IV Estimation (Thailand and Vietnam)

Variables	Prod_Inn	Proc_Inn	Org_Inn	Prod_Inn	Proc_Inn	Org_Inn
	Thailand			Vietnam		
Predicted R&D Intensity	3.1872 (1.9691)	-.3992 (1.9257)	1.1806 (2.0661)	.3630*** (.0543)	.3938*** (.0567)	.1912*** (.0553)
Technological Cooperation	1.2958*** (.2176)	1.3893*** (.2223)	.5752*** (.2252)	.5859*** (.1379)	1.3563*** (.1837)	.2732* (.1470)
Subcontract	.5919** (.2966)	2.2477*** (.3725)	-.6913 (.5125)	.0274 (.1447)	-.0668 (.1489)	.0492 (.1679)
Email	-.3213 (.2023)	.0970 (.1798)	-.0421 (.2482)	.1577 (.2117)	-.0110 (.1885)	-.3553 (.2528)

Website	.4298 .(1961)	.6896*** (.1581)	.6376*** (.2177)	.2981*** (.1012)	.3604*** (.1011)	.5912*** (.1229)
Medium	.0216 (.1605)	.2293 (.1402)	.3281* (.1796)	-.0713 (.1148)	-.2537** (.1135)	.3183** (.1399)
Large	-.4950** (.2065)	-.6371*** (.1791)	.0533 (.2104)	-.2168* (.1280)	-.3805 (.1298)	.2091 (.1496)
Capital Intensity	-.1097*** (.0380)	.0110 (.0352)	-.0240 (.0412)	-.0374 (.0319)	-.0128 (.0310)	-.0125 (.0385)
Educated Labor Force	.0982 (.0790)	.5272*** (.0683)	.4709*** (.0767)	.0188 (.0492)	.2496*** (.0496)	.2320*** (.0543)
Training Decision	.6400*** (.1647)	1.1625*** (.1525)	.5818*** (.1705)	.6483*** (.1069)	.7138*** (.1152)	.7394*** (.1166)
Constant	-.4222 (.4370)	-2.3275*** (.4179)	-2.4536*** (.4969)	-.9220 (.6289)	-.9207 (.6119)	-1.9120 (.7616)
Observation	1000	1000	1000	995	995	985
ISIC-2 digit dummy	Yes	Yes	Yes	Yes	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.4.13 Productivity Function Using IV estimation (Thailand and Vietnam)

Variables	Sales per Worker (Thailand)	Sales per Worker (Vietnam)
Capital Intensity	.3861*** (.0544)	.2069*** (.0776)
Firm Size	.0155 (.0709)	-.0121 (.0877)
Predicted Product Innovation	2.6554** (1.1257)	2.8919* (1.6802)
Predicted Process Innovation	-2.0488** (.8372)	-.7054 (1.0554)
Predicted Organizational Innovation	.3402 1.2990	-1.2999 (1.3594)
Constant	8.9779 (.6777)	15.3795*** (1.5400)
Observation	1000	996
ISIC-2 digit dummy	Yes	Yes

Note: p<0.01(***), p<0.05(**), p<0.10(*). Standard errors are in parentheses.

Table A.5.1 Four Types of Industries

SITC	Industries
Growing Industries	
High-tech	
579	Waste, parings and scrap, of plastics (process)
784	Parts & accessories of vehicles of 722, 781, 782, 783 (automotive)
884	Optical goods, n.e.s. (engineering)
885	Watches & clocks (engineering)
Low-tech	
75	Spices (primary)
222	Oil seeds and oleaginous fruits (excluding flour) (primary)

231	Natural rubber & similar gums, in primary forms (primary)
246	Wood in chips or particles and wood waste (primary)
248	Wood simply worked, and railway sleepers of wood (agro-based)
288	Non-ferrous base metal waste and scrap, n.e.s. (other_resource)
613	Furskins, tanned or dressed, excluding those of 8483 (garment)
658	Made-up articles, of textile materials, n.e.s. (garment)
831	Travel goods, handbags & similar containers (garment)
841	Men's clothing of textile fabrics, not knitted (garment)
842	Women's clothing, of textile fabrics (garment)
843	Men's or boy's clothing, of textile, knitted, croche. (garment)
844	Women's clothing, of textile, knitted or crocheted (garment)
845	Articles of apparel, of textile fabrics, n.e.s. (garment)
851	Footwear (garment)
Emerging Industries	
High-tech Industries	
267	Other man-made fibres suitable for spinning (process)
512	Alcohols, phenols, halogenat., sulfonat., nitrat. der. (process)
513	Carboxylic acids, anhydrides, halides, per.; derivati. (process)
575	Other plastics, in primary forms (process)
679	Tubes, pipes & hollow profiles, fittings, iron, steel (process)
716	Rotating electric plant & parts thereof, n.e.s. (electronics)
743	Pumps (excluding liquid), gas compressors & fans; centr. (eng)
746	Ball or roller bearings (engineering)
752	Automatic data processing machines, n.e.s. (electronics)
759	Parts, accessories for machines of groups 751, 752 (electronics)
763	Sound recorders or reproducers (engineering)
771	Electric power machinery, and parts thereof (electronics)
772	Apparatus for electrical circuits; board, panels (engineering)
773	Equipment for distributing electricity, n.e.s. (engineering)
776	Cathode valves & tubes (electronics)
785	Motorcycles & cycles (automotive)
813	Lighting fixtures & fittings, n.e.s. (engineering)
Low-tech Industries	
36	Crustaceans, mollusks and aquatic invertebrates (primary)
42	Rice (primary)
54	Vegetables (primary)
61	Sugar, molasses and honey (agro-based)
72	Cocoa (primary)
223	Oil seeds & oleaginous fruits (incl. flour, n.e.s.) (primary)
289	Ores & concentrates of precious metals; waste, scrap (other_rb)
422	Fixed vegetable fats & oils, crude, refined, fract. (agro-based)
592	Starche, wheat gluten; albuminoidal substances; glues (other_rb)
612	Manufactures of leather, n.e.s.; saddlery & harness (garment)
821	Furniture & parts (lt_other)
Losing Industries	
High-tech Industries	
266	Synthetic fibres suitable for spinning (process)
671	Pig iron & spiegeleisen, sponge iron, powder & granu (process)
722	Tractors (excluding those of 71414 & 74415) (engineering)

723	Civil engineering & contractors' plant & equipment (engineering)
728	Other machinery for particular industries, n.e.s. (engineering)
731	Machine-tools working by removing material (engineering)
733	Mach.-tools for working metal, excluding removing mate. (engineering)
735	Parts, n.e.s., & accessories for machines of 731, 733 (engineering)
737	Metalworking machinery (excludingmachine-tools) & parts (engineering)
742	Pumps for liquids (engineering)
744	Mechanical handling equipment, & parts, n.e.s. (engineering)
745	Other non-electr. machinery, tools & mechan. appar. (engineering)
749	Non-electric parts & accessor. of machinery, n.e.s. (engineering)
764	Telecommunication equipment, n.e.s.; & parts, n.e.s. (electronics)
781	Motor vehicles for the transport of persons (automotive)
782	Motor vehic. for transport of goods, special purpo. (automotive)
786	Trailers & semi-trailers (process)
791	Railway vehicles & associated equipment (process)
792	Aircraft & associated equipment; spacecraft, etc. (ht_other)
793	Ships, boats & floating structures (engineering)
811	Prefabricated buildings (engineering)
874	Measuring, analysing & controlling apparatus, n.e.s. (ht_other)
891	Arms & ammunition (engineering)
Low-tech Industries	
1	Live animals other than animals of division 03 (primary)
12	Other meat and edible meat offal (primary)
34	Fish, fresh (live or dead), chilled or frozen (primary)
35	Fish, dried, salted or in brine; smoked fish (agro-based)
44	Maize (not including sweet corn), unmilled (primary)
232	Synthetic rubber (agro-based)
245	Fuel wood (excluding wood waste) and wood charcoal (primary)
247	Wood in the rough or roughly squared (agro-based)
251	Pulp and waste paper (agro-based)
281	Iron ore and concentrates (other_rb)
287	Ores and concentrates of base metals, n.e.s. (other_rb)
634	Veneers, plywood, and other wood, worked, n.e.s. (agro-based)
681	Silver, platinum, other metals of the platinum group (primary)
Marginal Industries	
High-tech Industries	
541	Medicinal and pharmaceutical products, excluding 542* (ht_other)
533	Pigments, paints, varnishes and related materials (process)
778	Electrical machinery & apparatus, n.e.s.* (ht_other)
581	Tubes, pipes and hoses of plastics (process)
571	Polymers of ethylene, in primary forms (process)
572	Polymers of styrene, in primary forms (process)
591	Insectides & similar products, for retail sale (process)

593	Explosives and pyrotechnic products* (process)
672	Ingots, primary forms, of iron or steel; semi-finis. (process)
721	Agricultural machinery (excluding tractors) & parts (engineering)
741	Heating & cooling equipment & parts thereof, n.e.s.* (engineering)
Low-tech Industries	
11	Meat of bovine animals, fresh, chilled or frozen (primary)
25	Birds' eggs, and eggs' yolks; egg albumin (primary)
47	Other cereal meals and flour (agro-based)
48	Cereal preparations, flour of fruits or vegetables (agro-based)
57	Fruits and nuts (excluding oil nuts), fresh or dried* (primary)
58	Fruit, preserved, and fruit preparations (no juice)* (agro-based)
59	Fruit and vegetable juices, unfermented, no spirit (agro-based)
62	Sugar confectionery (agro-based)
81	Feeding stuff for animals (no unmilled cereals) (primary)
91	Margarine and shortening (primary)
98	Edible products and preparations, n.e.s. (agro-based)
112	Alcoholic beverages (agro-based)
121	Tobacco, unmanufactured; tobacco refuse* (primary)
122	Tobacco, manufactured (agro-based)
211	Hides and skins (except furskins), raw (primary)
212	Furskins, raw, other than hides & skins of group 211 (primary)
265	Vegetable textile fibres, not spun; waste of them (agro-based)
269	Worn clothing and other worn textile articles (agro-based)
273	Stone, sand and gravel (primary)
277	Natural abrasives, n.e.s. (incl. industri. diamonds) (primary)
278	Other crude minerals (primary)
282	Ferrous waste, scrape; remelting ingots, iron, steel* (other-rb)
283	Copper ores and concentrates; copper mattes, cemen* (other-rb)
321	Coal, whether or not pulverized, not agglomerated (primary)
322	Briquettes, lignites and peat (other-rb)
325	Coke & semi-cokes of coal, lign., peat; retort carbon (other-rb)
335	Residual petroleum products, n.e.s., related mater. (other-rb)
421	Fixed vegetable fats & oils, crude, refined, fractio. (agro-based)
431	Animal or veg. oils & fats, processed, n.e.s.; mixt. (agro-based)
511	Hydrocarbons, n.e.s., & halogenated, nitr. derivative (other-rb)
514	Nitrogen-function compounds (other-rb)
515	Organo-inorganic, heterocycl. compounds, nucl. acids (other-rb)
531	Synth. organic colouring matter & colouring lakes (other-rb)
532	Dyeing & tanning extracts, synth. tanning materials (other-rb)
551	Essential oils, perfume & flavour materials (other-rb)
611	Leather (garment)
629	Articles of rubber, n.e.s. (agro-based)
642	Paper & paperboard, cut to shape or size, articles (lt_other)
655	Knitted or crocheted fabrics, n.e.s. (garment)
656	Tulles, trimmings, lace, ribbons & other small wares (garment)
657	Special yarn, special textile fabrics & related (garment)
661	Lime, cement, fabrica. constr. mat. (excludingglass, clay) (other-

	rb)
665	Glassware (lt_other)
667	Pearls, precious & semi-precious stones* (other-rb)
673	Flat-rolled prod., iron, non-alloy steel, not coated (lt_other)
676	Iron & steel bars, rods, angles, shapes & sections (lt_other)
678	Wire of iron or steel (lt_other)
682	Copper (primary)
683	Nickel (primary)
684	Aluminium (primary)
685	Lead* (primary)
686	Zinc (primary)
687	Tin (primary)
694	Nails, screws, nuts, bolts, rivets & the like, of metal (lt_other)
699	Manufactures of base metal, n.e.s. (lt_other)
846	Clothing accessories, of textile fabrics* (garment)
848	Articles of apparel, clothing access., excluding textile* (garment)
893	Articles, n.e.s., of plastics* (lt_other)
894	Baby carriages, toys, games & sporting goods* (lt_other)
895	Office & stationery supplies, n.e.s. (lt_other)
899	Miscellaneous manufactured articles, n.e.s. (lt_other)

Source: International Trade Center, 2020