Ph.D. Dissertation in Engineering

The Internal and External Effects of Knowledge Sources with Implications for the Middle-Income Trap: A Comparative Study between Korea and Thailand

지식 원천의 내외부적 효과와 중간소득함정에 대한 시사점: 한국과 태국 간의 비교연구

August 2019

Seoul National University

Graduate School of Seoul National University

Technology Management, Economics, and Policy Program

Sira Maliphol

The Internal and External Effects of Knowledge Sources with Implications for the Middle-Income Trap: A Comparative Study between Korea and Thailand

Advisor: Jeong-Dong Lee

I submit this dissertation in partial fulfilment of the requirements towards a doctoral degree in engineering

August 2019

Graduate School of Seoul National University

Technology Management, Economics, and Policy Program

Sira Maliphol

Chair	Yoonmo Koo	(Sign)
Vice-Chair	Jeong-Dong Lee	(Sign)
Member	Sangook Park	(Sign)
Member	Chulwoo Baek	(Sign)
Member	Won-Sik Hwang	(Sign)

Dedicated to my late mother,

Pisamai,

for allowing me to dream

Abstract

The Internal and External Effects of Knowledge Sources with Implications for the Middle-Income Trap:

A Comparative Study between Korea and Thailand

Sira Maliphol

Technology Management, Economics, and Policy Program

The Graduate School

Seoul National University

The middle-income trap is caused by the failure to grow an economy through the structural change of an economy. Structural change can be actualized through production and innovation capabilities. Whether or not the structural change leads to growth, however, depends on whether or not the source of growth is innovation-driven. Thus, innovation transition failure can lead to the middle-income trap (Lee et al., 2019). This dissertation provides a comparative study on the patterns of capabilities development of Korea and Thailand to examine the differences in the transition process.

Most studies on innovation systems focus on advanced countries that tend to leave out differing drivers of productivity and economic growth for developing countries. Developing countries at the lower ranges of income must,

thus, find ways to transition to innovation-based growth with few reliable models to follow. This dissertation distinguishes catching up from transition by the source of growth; catching up does not usually differentiate between efficiency-driven growth and innovation-driven growth. This study represents an exploratory work because there have not been previous studies on innovation transition failure in the past. This dissertation focused on the potential causes of innovation system transition and by extension its failure. Since knowledge accumulation drives innovation, the three studies focus on measuring knowledge flows and accumulation through different types of knowledge networks and identifies the determinants and institutions of accumulation of the different types of knowledge.

Chapter 2 is a quantitative study that examines the effects of different types of knowledge flows on the productivity growth of two different types of economies: a national innovation system that has successfully transitioned, i.e. Korea, and a national innovation system that has failed to transition, i.e. Thailand. Korean industrial sectors are driven by innovation capabilities that are dependent on R&D activity and its related spillovers. Therefore, foreign sources of production capabilities, via inward FDI, are not expected to have positive effects on productivity growth. In Thailand, production capabilities are still the main and only significant drivers of growth overall. While disembodied knowledge flows from industrial sector R&D activity have a significant and positive effect on productivity, the overall effects are negative. The scale and efficiency of learning through R&D needs to be increased across the economy.

Chapter 3 presents a study that takes a double-sided approach in examining the automotive industries in Korea and Thailand. First, a network analysis approach is used to provide a snapshot of the strength of two main flows of knowledge networks in an innovation system: embodied and disembodied. The embodied and disembodied networks show the relative strengths of industrial sector knowledge flows in comparison to each other and within each country. The knowledge networks in Korea are stronger, and they have also strengthened over time when measured by the economic and technological systems and subsystems. The knowledge networks in Thailand present a more ambiguous outcome. Again, the main growth in the knowledge networks comes from non-R&D related activity.

The second part of chapter 3 examines the sectoral innovation system to understand the underlying dynamics of change. The actors at the top of the industries within the systems have remained the same in both countries with most firms exiting at the bottom, which should be expected. From a global perspective, however, the difference in catch-up is quite different. Hyundai is the only remaining Korean automaker. Its survival is based largely on its innovation capabilities that were nurtured by institutions within the sectoral innovation system that allowed it to eventually compete against global leaders. In contrast, the top firms in the auto industry of Thailand are still foreign MNCs that have continued to consolidate the market through foreign innovation capabilities.

Chapter 4 turns to a national perspective. Taking a national innovation systems perspective, Korea has managed to develop globally competitive firms with strong innovation capabilities in several industries, e.g. Hyundai, Samsung, and LG. In Thailand, the lack of innovation system transition is taken as an underlying cause of the middle-income trap in Thailand. Similar to the auto sector examined in chapter 3, MNCs dominate the biggest manufacturing sectors for similar reasons. The sectors where the largest companies operate in Thailand are protected from competition, disincentivizing development of innovation capabilities. The national innovation system has had weak actors (Intarakumnerd et al., 2002) that have not markedly changed in their innovation capabilities. The study finds that the institutions and policies that affect knowledge accumulation were late to form and even slowed the process of accumulation.

The implications for the studies in this dissertation emphasize the different types of knowledge that drive innovation capabilities. Variation between the sources of productivity growth by knowledge type is an important aspect of innovation transition and therefore growth. Realignment of institutions that affect the trade and economic structures are likely to upset incumbents that are vested in the existing structures and institutions that support them. While capabilities grow in complexity, part of the complexity is that new capabilities must be added to existing capabilities, increasing management complexity. Further implications are that government policies can be used to encourage “artificial” demand for innovation capabilities that support knowledge flows through multiple channels. Since R&D expenditure is already targeted, policies should try to find ways to increase the innovation effects of knowledge workers more efficiently and rapidly for the different types of knowledge.

The main contributions of the study are examining technology capabilities in more discrete forms based on the type of knowledge flow in an economy and quantifying the change in knowledge networks of innovation systems using dichotomous matrices of IO data of embodied and disembodied knowledge channels.

Keywords: Middle-income trap; Innovation systems; Innovation transition failure; Types of knowledge

Student Number: 2013-31308

Contents

List of Tables

List of Figures

Chapter 1.
Introduction

1.1. Background

A large majority of countries in middle-income in 1960 are still in middle-income despite the passage of several decades (World Bank, 2013). Middle-income countries look to escape economic growth traps, which, in the long-term, stem from a lack of technological change. Since economic growth is attributed to technological change (Solow, 1957; 1962), developing countries were expected to catch up quickly as technologies created in wealthier countries disseminated globally (Gerschenkron, 1962; Mathews, 2002; Hobday, 2003). Rather, the economic convergence of country incomes did not occur, and countries of similar income-levels tend to move together and to grow apart from other income-levels (Baumol, 1986; Quah, 1993).

Structural changes drive economic growth when resources move to more productive sectors but can also drive short-term catch-up that eventually slows into a "middle-income trap" (Lewis, 1954; Kuznets, 1955; Hausman et al, 2004; McMillan and Rodrik, 2014; Eichengreen et al., 2014; Aiyar et al., 2013). What the middle-income trap means, however, is not precisely defined. So, rather than contend with the studies that debate the existence of the middle-income trap, this dissertation considers how developing countries transition from innovation systems employing efficiency-seeking strategies—or not transition—to those that use innovation-driven strategies. If economies do not reach high-income, then the failure to transition to innovation-driven economies may lead to the middle-income trap as a result of a "middle-innovation trap" (Lee et al., 2019).

The concept of structural change introduced the economic idea that economies needed to shift their resources towards more productive segments of their economic systems (Lewis, 1954; Kuznets, 1955). Studies establishing a link between economic change and learning (Arrow, 1962; Bell, 1973) suggested that this process was easier said than done. Learning involves the process of absorbing knowledge and transforming that knowledge into output, which can take many forms of inputs and outputs (Zahra and George, 2002). At the national level, innovation is required to achieve economic development in high-income countries. Lower-income countries, however, can drive economic growth through efficiency-seeking strategies, using an advantage of lower cost of labor. Thus, middle-income countries lose low-wage cost competitiveness as they increase their GDP per capita. In order to escape middle-income, they must transition their economic structures towards innovation-based growth.

The success or failure to transition to high-income is linked to innovation but the process of transition is not fully understood. Economic development is linked to deliberate efforts to "catch up" and intensive learning (Wong, 1999). While firms are considered the central actor of innovation, innovation is most greatly affected by aspects of sectoral innovation systems (Malerba, 2002; 2004). Learning that most affects innovation directly occurs by firms within sectors. The interactions of the national and sectoral innovation systems, however, are important in the development process (Malerba and Nelson, 2011). Therefore, this dissertation considers sectoral innovation failure as an underlying cause of the middle-income trap and how policies affecting knowledge flows have been and can be applied to escape it. This dissertation distinguishes catching up from transition by the source of growth; catching up does not usually differentiate between efficiency-driven growth and innovation-driven growth.

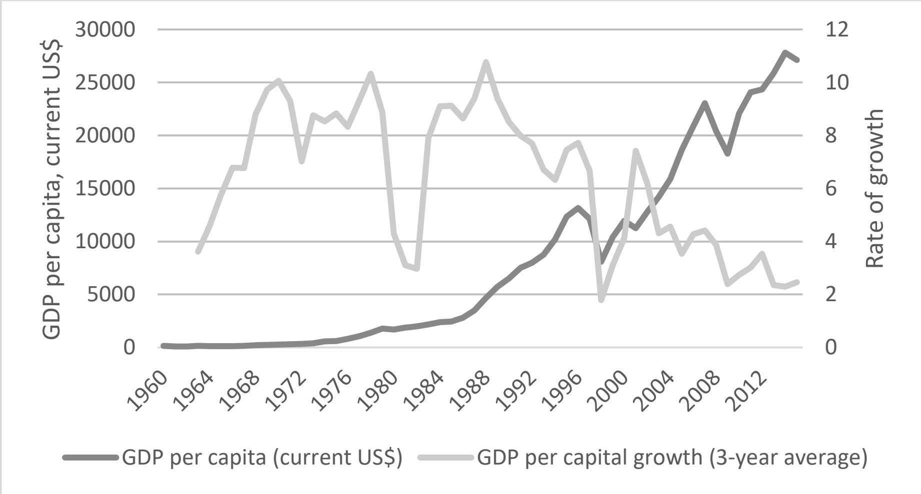
The few countries that managed the shift to innovation-driven growth applied industrial policies enabling high economic growth rates, e.g. South Korea and Taiwan, necessary to reach high-income levels. Other countries like Thailand have followed suit, adopting industrial policies targeting specific sectors, usually in “high-tech” manufacturing such as airplanes, automobiles, pharmaceuticals, semiconductors, and ICT. Yet, few of these countries have been successful. Since learning or the accumulation of knowledge is necessary for innovation, economic development traps can be viewed as the failure to accumulate sufficient knowledge for sectoral innovation or a sectoral innovation transition failure.

This dissertation takes an evolutionary economics approach, which emphasizes dynamics, innovation processes, and economic transformation (Nelson and Winter, 1982). This study examines how innovation system transition failure occurs at the national level and at the sectoral level. The implications for how the innovation transition or failure occurs are considered.

1.2. Two tales of the middle income trap: Korea and Thailand

Two countries that were middle-income in 1960 provide an interesting comparison to understand the effects of accumulation of knowledge and growth: Korea and Thailand. The first is Korea, which is known as one of the “Four Asian Tigers” and “the Miracle on the Han River” because of its industrialization and fast growth. Through active policy engagement, Korea managed to develop large conglomerates or chaebols that innovate within their respective sectors and drove the GDP per capita from middle-income to high-income levels by the early 1990s (figure 1-1). After its bout with the Asian Financial Crisis in the latter half of that decade, Korea continued to develop at relatively decent rates of growth (figure 1-1). Korea, now a high-income country, has become an economic powerhouse more interested in full innovation transition than economic transition.

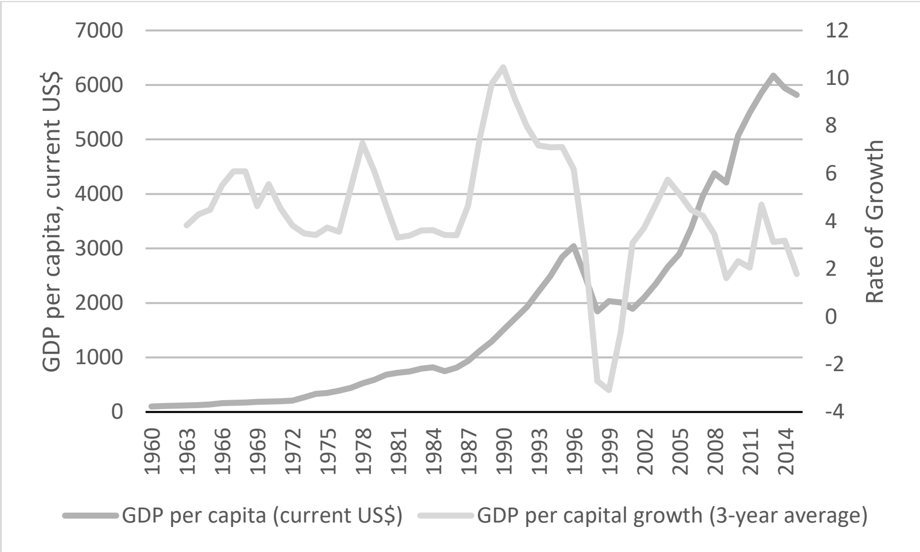
Figure 1-1: GDP per capita and per capita growth, Korea 1960-2015



Source: World Development Indicators, World Bank and author's calculation.

The other is Thailand, which is also considered a newly industrializing economy in a later group of countries, even once labeled a "New Asian Tiger." In contrast to Korea, Thailand is still a middle-income country that has yet to escape the middle-income trap after the passage of several decades (figure 1-2), belying its earlier, prematurely given moniker. Moreover, its rate of growth has slowed to low single-digits that will leave it in middle-income for decades more (figure 1-2). Together, these two countries provide an interesting contrast that proves instructive in the process of economic and innovation system transition between middle- and high-income.

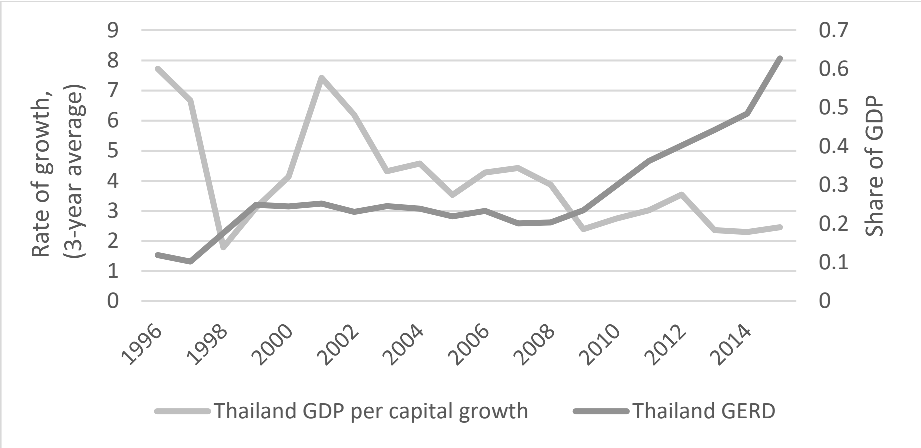
Figure 1-2: GDP per capita and per capita growth, Thailand 1960-2015



Source: World Development Indicators, World Bank and author's calculation.

Moreover, general strategies that target only macroeconomic growth seem to be ineffective. Thailand has increased the rate of R&D expenditures yet has little to show in terms of economic growth (figure 1-3). When the economy was growing the fastest, there was little R&D investment. Thus, the relationship between R&D expenditures and economic growth is more complicated than aggregate analysis can suggest. The process of technological capabilities transition depends on the flows of knowledge within an innovation system.

Figure 1-3: GDP rate of growth vs. R&D expenditure, share of GDP



Source: World Development Indicators, World Bank and author's calculation

As a learning economy, Korea has proven that its innovation system is resilient and managed to coevolve with the changing institutions that have held back so many other countries like Thailand. From a global perspective, the exogenous shocks and external institutions that affected Korea were the same as those that affected Thailand. As with many other developing countries during the Cold War period, the government responses were nearly identical with respect to industrialization and globalization. It did not take long for Korea to change its strategies but the strategies were neither obvious nor easy to apply, so what explains the stark difference and divergence? I posit that the process of knowledge accumulation and the related aspects of knowledge organization are the main determinants that can explain the difference, especially for innovation capabilities. Learning capabilities capture and translate value into greater value through intentional learning activities that leads to a process of technological change that can vary depending on the direction and intensity of those activities. Thus, knowledge flows affect learning capabilities by increasing productivity of technological capabilities. Industrial sector embodied and disembodied knowledge flows are considered as a starting point of this research. Then, the interindustry knowledge networks or channels of embodied and disembodied knowledge flows are examined. Finally, a comparative study of national innovation systems in country-industries is considered to understand their effects on the process of transition from production-oriented to innovation-driven growth.

1.3. Structure of the thesis: From meso to macro

How, then, does sectoral innovation transition failure happen? Drawing from innovations systems literature (Edquist, 1997; Freeman, 1987; Lundvall, 1992; Malerba, 2002; Nelson, 1992), I examine this question considering knowledge stocks and flows along knowledge networks to find possible causes of sectoral innovation transition failure. Production-driven growth is efficiency-oriented, which means it depends on costs of inputs. Sustained growth in industrial sectors is dependent on innovation-based, knowledge accumulation aspects of a sector. First, if knowledge is necessary for economic activity and growth, knowledge must be defined. Knowledge can be embodied in production technology and transferred through transactions. Otherwise, knowledge generally accumulates through a process of learning directly through R&D activity and indirectly through spillovers. Knowledge flows between industrial sectors represent the use of knowledge in production and are transmitted through embodied and disembodied channels. Thus, I examine how the embodied and disembodied knowledge is transmitted between industries and affect productivity.

Second, knowledge networks are important aspects of how knowledge is transmitted within innovation systems. Thus, I consider the aspects of the networks of innovation systems through which knowledge flows, specifically the embodied and disembodied channels mentioned earlier. The strength of the knowledge flow networks depends on the learning capabilities that should increase as innovation capabilities develop. Quantitative measures, however, are generally missing in previous studies, so I first attempt to measure the innovation transition process of innovation networks using dichotomous matrices of IO data. Once quantified, the transition process is statistically tested to determine the significance of the changes.

If knowledge accumulation occurs at different rates between firms, industries, and countries, then there must be differences in the institutions within the innovation systems that account for the disparity. In the innovation systems literature, complexity of innovation is examined through firms and other innovation actors and how they are related through networks and institutions at the sectoral level to compare the country-sectors of the automotive sectors in Korea and Thailand. The automotive industry is one sector that has long been targeted by a long list of middle-income countries including Brazil, China, Korea, Malaysia, Taiwan, Thailand, and Turkey. Yet, Korea is the only developing country that has successfully entered and competes at the top of the industry. A sectoral innovation systems approach is applied to understand the divergence between Korea and Thailand.

Since the middle-income trap is a national phenomenon, chapter 4 examines whether there are national patterns of development of the national innovation systems in Korea and Thailand to identify possible causes. The determinants found at the sector level in the auto industry are reflected across some sectors in the national innovation system, but there are also national institutions that constrain development of innovation capabilities as well.

The innovation trap is explored by comparing Korea and Thailand in the following chapters. In chapter 2, the knowledge networks are examined to determine how industrial sector knowledge flows affect the industrial growth. In Chapter 3, I consider the potential for the lack of knowledge accumulation for transition failure of the sectoral innovation system across the countries and then examine the automotive industry in Korea and Thailand for differences. In Chapter 4, I compare the national innovation systems in Korea and Thailand to find potential causes of the middle-income trap by innovation transition failure in Thailand. In Chapter 5, I provide a summary of the findings and discussion on the implications including the limitations and suggestions for further research.

1.4. Contributions of Study

To the best of my knowledge, this dissertation is one of the first studies that focuses on innovation systems transition and failure. The three main studies in the dissertation focus on identifying the underlying cause of innovation transition, and thus failure. To identify the differences in the determinants of innovation performance, however, requires the separation of technological capabilities beyond the traditional production and innovation capabilities.

Furthermore, the patterns of capabilities development and related types of knowledge are essential aspects that have been examined only separately in previous studies.

Based on IO models of knowledge networks of the industrial structures in the innovation systems in Korea and Thailand, chapter 2 provides an empirical study of the impact of different types of knowledge, technology transfer and embodied and disembodied knowledge flow networks, on the productivity growth of industrial sectors. The comparative study between Korea and Thailand demonstrate the differences of types of growth depending on the level of innovation transition in each country.

Since there has not been a quantitative study of the sectoral innovation transition, the study in chapter 3 is an exploratory study that is divided into two parts. Using a similar IO construct of the knowledge networks in the innovation system of the two countries, the first part of chapter 3 uses network analysis to quantify the sectoral innovation system transition of the industrial sectors in Korea and Thailand. The second part of the study uses a sectoral innovation systems approach to understand the possible underlying causes of sectoral innovation transition or its failure of one of the main sectors targeted by industrial policies in both countries, the automotive sector.

The final chapter extends these studies to link innovation system transition to describe how to escape from the middle-income trap. By comparing the two countries, the failure to transition the national innovation system provides the theoretical explanations of how a country falls into the middle-income trap.

Chapter 2.

Networks of knowledge flows and its impact on the sectoral growth in Korea and Thailand

2.1. Introduction

Productivity is the driver of sustained economic growth. Past studies on the middle-income trap show that productivity slowdowns are the main determinant for slowdowns as middle-income countries approach high-income (Eichengreen et al., 2014). Transition towards innovation-driven growth is suspected as the cause of this slowdown (Bulman et al., 2017; Paus, 2017). The causes of the slowdowns, however, have not been pinpointed but sources of growth are suspected to change between middle-income and high-income. The aim of this chapter is to demonstrate the difference of sources of productivity growth between Korea and Thailand can be found in the types of industrial sector knowledge flow networks.

In order to increase productivity, knowledge must be accumulated through learning. Knowledge bases are important aspects of innovation systems (Edquist, 1997; Lundvall, 1992; Malerba, 2002; Nelson, 1992). The sectoral and national levels of innovation systems are important for economic development (Malerba and Nelson, 2011). One of the suspected causes of why Thailand has started to diminish its rate of growth is because its firms in aggregate have not developed strong learning capabilities to accumulate knowledge at the sectoral level. Knowledge accumulation is dependent on knowledge creation and knowledge transmission. Considering different sources of knowledge, this chapter considers how knowledge is transmitted to industrial sectors and leads to increased productivity, or not.

Studies on economic growth in advanced countries focus on innovation-driven growth because efficiency-focused approaches are more difficult to achieve in high-income populations. In developing countries, however, efficiency-oriented strategies are effective, making technology transfer an attractive means to increase productivity rapidly. Therefore, several forms of knowledge transmission are considered in this study to understand the difference in the process of transition from middle-income to high-income: technology transfer and knowledge flows through embodied and disembodied channels.

This chapter is an empirical quantitative study on the sources of productivity growth from different sources of technology transmission. South Korea and Thailand are compared because Korea is former middle-income country that is recently high-income using technology-oriented strategies. Thailand is still in middle-income and faces declining rates of economic growth. Technology transfer is expected to be a main driver of growth for Thailand and less likely to be a driver a growth for Korea. Instead, productivity growth rates in Korea, as a high-income country, are expected to be driven by knowledge accumulation strategies through learning, i.e. R&D activity and knowledge flows resulting from that activity. Knowledge flows are examined through embodied and disembodied channels. Since innovation capabilities in developing countries are weaker than in developed countries, disembodied knowledge flows are expected to have weaker effects on productivity growth than in developed countries. If innovation capabilities are particularly weak, then disembodied channels of knowledge flows may not have any significance.

The main argument of this chapter is that the development of industrial sector knowledge accumulation and knowledge flows are expected to drive growth through innovation. The sources of knowledge are expected to vary depending on the level of development of a country. In Korea, productivity is expected to be driven by R&D activity of an industrial sector through the interindustry knowledge flows, especially through disembodied channels. In Thailand, productivity is expected to be driven by efficiency-oriented technology transfer.

2.2. Literature review and theoretical framework

2.2.1. Productivity and knowledge sources

Knowledge is the main source of economic growth through technological change (Bell, 1973). Although technological change or innovation is defined as the main driver of economic growth, how innovation occurs in developing countries is still not well understood. Knowledge accumulation drives growth through technological and production capabilities, which differs between advanced and developing countries (Bell and Pavitt, 1993). Factors that enable middle-income countries to overcome the failure to transition to high income still focus on factor markets, i.e. factor productivity; institutional differences, i.e. intellectual property rights protection, macroeconomic policy, trade openness, democratic principles, inequality, and financial reform; and a few endogenous factors, i.e. education and innovation activities (Agenor, 2016). Vivarelli (2014) examines absorptive capacity, as specified by innovation literature, and entrepreneurial capabilities, from management studies, can be combined to better understand development research. Some theoretical studies that have included innovation components in later stage development that enables middle-income countries to become advanced ones (Vivarelli, 2014; Radosevic and Yoruk, 2016). Radosevic and Yoruk (2016) advise that a framework of technological capabilities across specialty, intensity, and global source is necessary for middle-income countries to advance and call for new relevant indicators to be created. Several studies have concluded that innovation transition is necessary for middle-income countries to avoid the middle-income trap as they develop economically (Bulman et al., 2017; Paus, 2017). To my knowledge, empirical studies that incorporate innovation transition into the middle-income trap thus far have been limited. This chapter examines different types of knowledge sources that drive industrial sector productivity and vary depending on technological capabilities.

Development through structural change occurs by industrializing in stages from imitation of production capabilities to innovation (Kim, 1997; Lall, 1992). Structural change is enabled by introducing technology to an economy that leads to a higher level of productivity than previously existed. To initialize the structural change or industrialization process, economies transfer technologies from abroad and grow more rapidly (Radosevic, 1999). Labor shifts from lower productivity sectors, e.g. agriculture, towards ones with higher productivity, e.g. manufacturing (Lewis, 1952; Kuznets, 1955). But without the introduction of new technology, markets will reach equilibrium at lower levels of development, based on the elasticities of substitution between capital and labor. For developing countries, the need to transition to innovation-driven growth is acknowledged but not well understood. Through a process of acquisition-assimilation-improvement, developing countries can develop innovation capabilities (Kim, 1998). The production process can be divided into different components that enable gradual technological development in different segments of production that incrementally develop OEM and OBM components [1] within the production process (Hobday, 1995; 2003). This approach combined the concept of technological availability with sector targeting, which inspired industrial policy in many countries, mostly in East Asia. Yet, how latecomer countries end up transitioning from production to innovation capabilities is only partially described. Moreover, developing countries in Latin America and Africa have not managed to develop the innovation capabilities to successfully transition their innovation systems despite structural change (McMillan and Rodrik, 2014). What enables the successful creation of innovation capabilities when production capabilities are prevalent is still unclear.

The transition to innovation-driven growth suggests the need for an appropriate innovation strategy during the transition period. Earlier studies find that imports and FDI drive productivity growth in developing countries (Acemoglu et al. 2006; Falvey et al., 2004). Acemoglu et al. (2006) finds that

[1] An OEM is an original equipment manufacturer and an OBM is an original brand manufacturer. The differences refer to the ownership of technology that is used in the manufacturing process.

early stage developing countries use more investment-driven strategies and those closer to the technological frontier switch to innovation-driven strategies. Structural changes occur in middle-income countries as they enter and leave the income band. Previous studies, however, have not empirically distinguished the impacts of innovation on economic growth within and between sectors. Most studies of innovation impacts would be classified as within-sector effects. There has not, however, been specific research into how innovation differs in its impacts between sectors. Innovation studies lay the theoretical groundwork. In other words, knowledge-based innovation capabilities is expected to be important in developed countries because their income levels make efficiency harder to achieve. Yet, in developing countries which have lower labor costs, efficiency-driven production capabilities are still effective means of productivity growth.

2.2.2. Different types of knowledge networks

Technology transfer

Technology transfer is an earlier form of technology capability building that is formed in a developing country (Radosevic, 1999). Production capital that is introduced into an economy increases the existing productivity of the economy when the technology does not exist in the production economy of the host country. This process depends on factor cost differences between home and host countries. When knowledge is embodied in production capital, the skills that are required of human capital are minimized. Moreover, production capital and its operational knowhow can be transferred through transactions between firms that is usually measured through FDI between countries.

Inward FDI can be used for resource-seeking, market-seeking or efficiency-seeking purposes to access new markets or lower costs of labor (Rugman and Verbeke, 2001). Resource-seeking involves access to technology that does not exist in a home economy. Market-seeking leverages technological advantages in a host economy. Efficiency-seeking leverages technological advantages combined with lower wages in a host economy to export products back to the home economy or other export markets. Since developing countries lack technology capabilities, however, the motivation for inward FDI is limited to market- and efficiency-seeking motivations. Previous studies have used inward FDI as a proxy for knowledge flows through technology transfer in developing countries (Falvey et al., 2004).

Industrial sector knowledge flows through embodied and disembodied knowledge networks

Industrial sector knowledge creation is the learning activity performed within an industry. Knowledge creation depends on the pursuit of knowledge through R&D activity that leads to an increase in production output. This is most often proxied by the expenditure on R&D of an industrial sector. R&D activity itself, however, is not easily disaggregated into the different effects it may have on an industry. R&D activity can also lead to unintended knowledge spillovers. Spillovers are the unintended transfer of benefits that occur in transactions of knowledge exchange. Thus, knowledge accumulates through industrial sector R&D activity and the spillovers that occur as a result. These industrial sector knowledge flows are examined through the direct and indirect effects on productivity changes depending on whether it flows through embodied and disembodied knowledge networks.

Griliches (1979) divides spillovers into rent and knowledge types. Rent spillovers occur when knowledge is transferred beyond the transaction of that embodied in product goods. Similarly, knowledge spillover is when benefits are not appropriated and unintentionally accrue through R&D activities. These spillovers flow through embodied and disembodied knowledge channels, respectively. Hwang and Lee (2014) extend the existing research by applying the framework to these different kinds of spillovers.

Empirical research on embodied knowledge flows is based on the early work of Terleckyj (1980) that measures the amount of knowledge that flow through embodied knowledge channels. Empirical studies on disembodied knowledge flows is based on the work of Jaffe (1986) that uses patent weights to estimate the spillover effects. Verspagen (1997) examines disembodied flows of the USPTO and EPO data and finds that technology flows based on the probabilities in the Yale Concordance Table have positive effects on productivity growth. These studies, however, have been applied on data from advanced countries (table 2-1).

Previous studies attempt to quantify these interactions using input-output (IO) relationships of R&D expenditure to model the structural and systemic aspects of the interactions between sectors in a national innovation system. Empirical studies on embodied and disembodied knowledge flows focus on developed countries (table 2-1). To the best of my knowledge, there are no similar studies for developing countries.

Table 2-1: Past studies on effects of interindustry knowledge flows

Channel	Study	Country Data
Embodied	Vuori (1997)	Finland
Embodied	Van Meijl (1997)	France
Embodied	Odagiri and Kinukawa (1997)	Japan (high-tech)
Embodied	Poetzsch (2017)	OECD (20)
Embodied	Scherer (1982)	United States
Embodied	Terleckyj (1980)	United States
Embodied	Wolff (1997)	United States
Disembodied	Verspagen (1997)	Europe, US
Disembodied	Medda and Piga (2014)	Italy
Disembodied	Branstetter (2001)	Japan, United States
Disembodied	Lindstrom (1999)	Sweden
Disembodied	Jaffe (1986)	USA
Both	Hwang and Lee (2014)	Korea

Few studies have combined the different channels of knowledge flow. Hwang and Lee (2014) construct a model that combines both embodied and disembodied knowledge flows by using national account IO data and national patent data, respectively.

Since the failure to transition involves both production and innovation capabilities, productivity growth is expected to be tied to embodied knowledge flows. Developed countries, in contrast, would be expected to have positive effects from both embodied and disembodied knowledge flow channels.

This study aggregates industries groups that include nineteen sectors. Since patenting occurs mainly in the manufacturing sector, it is disaggregated into fourteen industries. The other broad sectors are aggregated separately. The industrial symbols and classifications are listed in table 2-2.

2.2.3. IO framework of interindustry knowledge flows

Technology transfer

The productivity production capital is wholly captured in the technology that is used to produce a given output. Thus, there is no interindustry spillover as a result. Thus, technology transfer may be considered a diagonal matrix of inflows of FDI.

Embodied knowledge flows

Many studies have used IO tables as a measure of knowledge flows from R&D activity. Final production cannot capture the interindustry transmission of technology and knowledge. Industry-level IO tables provide a structural mapping of interactions between industrial sectors. DeBresson (1996a; 1996b) finds that Leontief IO tables best capture the interactions between industrial sectors. Therefore, as has become convention, this study analyzes embodied knowledge flows through IO data.

The convention follows Terleckyj (1980), which assumes the amount of product-embodied spillover from industry *i* to industry *j* is proportional to the amount of intermediate goods sold from industry *i* to industry j. The coefficients of embodied knowledge flows, b_{ij}, are defined by:

$$b_{ij} = \frac{a_{ij}X_j}{X_i} \quad (1)$$

Where a_{ij} is the intermediate coefficients that describe the input *i* per unit output *j* and X_i is the total output of industry *i*.

Disembodied knowledge flows

The nature of disembodied knowledge makes it difficult to measure flows of disembodied knowledge because they are not directly traded in economic transactions. Jaffe (1986) is the first study to measure the "technological closeness" between firms based on the distribution of their patents over technology fields. Past studies define the flows through technological proximity between countries such as OECD members.

When considering interindustry linkages using patent data, a couple of issues arise. The construction of such linkages between patents and industries is labor-intensive and time-consuming. Kortum and Putnam (1997) used Canadian patents to construct a probability table and yielded the Yale Technology Concordance table (YTC). This was later replicated by the OECD using patent data from the European Patent Office (Johnson, 2002) and the Korean Intellectual Property Office (KIPO). Subsequent studies found that similar results are produced between the different concordance tables (Verspagen, 1997). Thus, following Hwang and Lee (2014), this study uses the KIPO technology concordance table for the probability matrix of interindustry spillover of disembodied knowledge.

The Korean technology concordance table was constructed using patent data from 900,604 applications between 2001 and 2006. The IPC classifications are then matched to standard industry classification (SIC) codes. Following the approach used by Jaffe (1986), the technological distance, td_{ij}, is calculated using the equation

$$td_{ij} = \frac{\boldsymbol{pat}_i \cdot \boldsymbol{pat}'_j}{\|\boldsymbol{pat}_i\| \cdot \|\boldsymbol{pat}_j\|} \tag{1}$$

where pat_i and pat_j are the position vectors of the respective industries i and j. The technological position vector is the probabilities of knowledge flow spillover from an industry across the 622 technological subclasses in an economy $\boldsymbol{pat}_i = [pat_{i1}, pat_{i2}, \ldots, pat_{i622}]$.

The disembodied knowledge flow from industry i to industry j, t_{ij}, is measured by knowledge produced in industry i, P_i, multiplied by the technological distance between it and another sector, j,

$$t_{ij} = P_i * td_{ij} \tag{2}$$

Thus, the disembodied knowledge flow matrix, T, is defined by

$$\boldsymbol{T} = \begin{bmatrix} t_{11} & \cdots & t_{1j} & \cdots & t_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{1j} & \cdots & t_{ij} & \cdots & t_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ t_{n1} & \cdots & t_{nj} & \cdots & t_{nn} \end{bmatrix} = \begin{bmatrix} P_1 t_{11} & \cdots & P_1 t_{1j} & \cdots & P_1 t_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ P_i t_{i1} & \cdots & P_i t_{ij} & \cdots & P_i t_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ P_n t_{n1} & \cdots & P_n t_{nj} & \cdots & P_n t_{nn} \end{bmatrix}$$

$$= \widehat{\boldsymbol{P}} \cdot \boldsymbol{td} = \widehat{\boldsymbol{P}} \cdot \boldsymbol{td}' \tag{3}$$

where $\widehat{\boldsymbol{P}}$ is the n x n diagonal matrix of patents granted by sector and $\boldsymbol{td}$ is a symmetrical n x n matrix of the technological distances.

The disembodied technology flow coefficient, c_{ij}, is the technology flow from industry *i* to industry *j*, t_{ij}, represented by

$$c_{ij} = t_{ij} \tag{4}$$

which is used in the following section.

2.2.4. Hypotheses

The main hypothesis is that different sources of knowledge have different impact on growth depending on the country-specific characteristics of its knowledge flow networks. What is the source of technological capability development in each country? An industry-driven, advanced country, i.e. Korea, is not expected to rely on technology transfer (via FDI) for productivity growth. Industrial sector R&D is expected to have positive impacts on productivity in Korea through knowledge creation and spillovers. Therefore, the development of interindustry knowledge networks flows will affect economic development. The differences in interindustry network characteristics affect how well the productivity of an industry develops. Specifically, the sources of knowledge will vary depending on the level of development of a country.

A well-established knowledge network of knowledge through technology transfer (via FDI) will have positively impact productivity in production-oriented developing economies, i.e. Thailand. With low levels of knowledge accumulation, learning capabilities through R&D activities are not expected to significantly drive productivity growth through knowledge creation and spillovers. Whether knowledge flows have positive effects on productivity growth is expected to differ depending on the channel of knowledge flows.

Interindustry effects through embodied and disembodied knowledge will depend on the level of innovation capability of the economy. Disembodied knowledge flows, based on patenting, require higher levels of innovation capabilities. Thus, while it may derive knowledge accumulation from embodied knowledge flows, Thailand is not expected to have effects of knowledge accumulation from disembodied knowledge flows.

Main hypothesis: The types of knowledge flow networks have different impact on growth depending on the country-specific characteristics of its knowledge flow networks

Inward FDI to industrial sectors is driven by efficiency-seeking motivations or by technology resource-seeking motivations:

Hypothesis 1a: Networks of knowledge through technology transfer (via FDI) may have a negative impact on a high-income country

Hypothesis 1b: A strong network of knowledge through technology transfer (via FDI) will positively impact productivity in developing economies that are production-oriented.

Industrial sector R&D activity is the main source of innovation but the impacts depend on the knowledge channels through which knowledge flows accumulate. Knowledge creation occurs through R&D activity but also leads to spillovers. Knowledge networks are modeled through embodied and disembodied channels. Embodied knowledge flows are expected to positively affect production in both advanced and developing countries if they participate in trade.

Hypothesis 2a: Since Korea has a high share of manufacturing in its economy, the effects of embodied knowledge flows are expected to be significant.

Hypothesis 2b: Similarly, the high level of manufacturing in Thailand is expected to lead to positive effects of embodied knowledge flows on productivity growth in its industrial sectors

Since disembodied knowledge flows are based on patent activity, they require higher levels of innovation capabilities.

Hypothesis 3a: As an advanced country, Korea is expected to have a positive relationship between disembodied knowledge flows and productivity growth

Hypothesis 3b: As a developing country, Thailand is not expected to have a positive relationship between disembodied knowledge flows and productivity growth

2.3. Methodology

2.3.1. Panel regression

Panel data has time-series and cross-sectional data aspects. Panel data is meant to separate the patterns according to different individuals, firms, or other object of study, in this case industries, over time. The dependent variable is the change in total factor productivity for an industry in time, *t*. Since the two countries are expected to "behave" differently as a result of different knowledge-related institutions, the study used two sets of panel data from Korea and Thailand.

When using panel data, omitted variables related to the industries may be expected. In order to test whether they may exist, the Hausman test is used to determine whether the effects are "random" or if the "fixed effects" should be used. The Hausman test checks to see if there are time-invariant error terms that are related to the dependent variable.

While dynamic models exist to estimate effects of panel data, e.g. GMM, these models require a longer set of observations than is available for this study. These models may be applied in future studies.

2.3.2. Data

Korea

The dataset for Korea covers the period from 2010 to 2015, the years which the subsets of the data overlap. The IO dataset comes from the Asian Development Bank, which provides value-added and capital stock values required to calculate total factor productivity (TFP) and the total and foreign intermediate input goods necessary for the IO matrices. Labor statistics are taken from the Bank of Korea. Inward FDI flows and FDI position (stock), and the R&D expenditure data are taken from the OECD FDI and STI Indicators databases. The R&D expenditure data for Thailand from 2010 to 2013 is taken from STI Office R&D Survey data. To calculate the wage-capital demand share, wage and value added data are taken from the National Accounts data for 2010, provided by the Bank of Korea. Patent counts are taken from the Korean Intellectual Property Information Service (KIPRIS).

The datasets are aggregated into nineteen common industrial classifications (table 2-2).

Table 2-2: Industrial symbols and classifications

Index	ISIC	Industry
1	AGR	Agriculture
2	MIN	Mining
3	FDP	Food, beverages, and tobacco
4	TXT	Textiles
5	LTH	Leather goods
6	WPP	Wood and pulp products
7	PUB	Paper and publications
8	CRP	Coke and refined petroleum products
9	CHM	Chemical products
10	RUB	Rubber and plastic products
11	NMT	Non-metal products
12	BMT	Basic and fabricated metal products
13	MCH	Machinery
14	ELM	Electrical machinery and apparatus n.e.c.
15	TRN	Transportation
16	MNF	Manufactured goods n.e.c.
17	EGW	Energy, gas, and water
18	CST	Construction
19	SVC	Services

The descriptive statistics and correlation matrices are provided for all economic and only manufacturing sectors in Korea (tables 2-4 and 2-5). Since collinearity problems arise when correlation is higher than 60%, the correlation matrix suggests that collinearity is not a problem for either Korean dataset (tables 2-6 and 2-7).

Table 2-3: Description of variable names for Korea (and Thailand)

Description	Variable
Change in productivity	dTFP
FDI stock growth rate	FDIRate
Rate of change in R&D spending growth rate	dRSofRS
Embodied spillover growth rate	dSEofSE
Embodied spillover from imports growth rate	dSEFofSEF
Disembodied spillover growth rate	dSDofSD

Table 2-4: Descriptive statistics, all economic sectors, Korea 2010-2013

Variable		Mean	Std. Dev.	Min	Max	Obs.
dTFP	overall	0.081	3.438	-12.749	12.800	N = 95
	between		0.061	-0.063	0.254	n = 19
	within		3.438	-12.757	12.791	T = 5
FDIRate	overall	0.090	0.422	-2.823	1.000	N = 95
	between		0.254	-0.520	0.637	n = 19
	within		0.341	-2.214	0.711	T = 5
dSEofSE	overall	-0.116	1.474	-11.507	1.000	N = 95
	between		0.521	-1.961	0.380	n = 19
	within		1.383	-9.663	2.795	T = 5
dSEFofSEF	overall	-0.030	1.191	-8.961	1.000	N = 95
	between		0.419	-1.434	0.301	n = 19
	within		1.118	-7.557	2.343	T = 5
dSDofSD	overall	0.089	0.098	-0.123	0.261	N = 95
	between		0.012	0.064	0.122	n = 19
	within		0.098	-0.099	0.227	T = 5

Table 2-5: Descriptive statistics, manufacturing sectors, Korea 2010-2013

Variable		Mean	Std. Dev.	Min	Max	Obs.
dTFP	overall	0.080	3.908	-12.749	12.800	N = 70
	between		0.035	0.031	0.152	n = 14
	within		3.908	-12.758	12.791	T = 5
FDIRate	overall	0.109	0.487	-2.823	1.000	N = 70
	between		0.294	-0.520	0.637	n = 14
	within		0.394	-2.195	0.730	T = 5
dSEofSE	overall	-0.147	1.618	-11.507	0.951	N = 70
	between		0.585	-1.961	0.182	n = 14
	within		1.515	-9.694	2.765	T = 5
dSEFofSEF	overall	-0.069	1.332	-8.961	0.939	N = 70
	between		0.473	-1.434	0.209	n = 14
	within		1.250	-7.595	2.304	T = 5
dSDofSD	overall	0.089	0.101	-0.123	0.261	N = 70
	between		0.014	0.064	0.122	n = 14
	within		0.100	-0.098	0.228	T = 5

Table 2-6: Correlation matrix, all economic sectors, Korea 2010-2013

		(1)	(2)	(3)	(4)	(5)
(1)	Change in productivity (dTFP)	1.000				
(2)	FDI stock growth rate (FDIRate)	-0.146	1.000			
(3)	Embodied spillover growth rate (dSEofSE)	0.325	0.059	1.000		
(4)	Embodied spillover from imports growth rate (dSEFofSEF)	0.301	0.030	na	1.000	
(5)	Disembodied spillover growth rate (dSDofSD)	0.178	-0.012	0.118	0.129	1.000

Note: na is non-applicable since these variables are not analyzed in the same model.

Table 2-7: Correlation matrix, manufacturing sectors, Korea 2010-2013

		(1)	(2)	(3)	(4)	(5)
(1)	Change in productivity (dTFP)	1.000				
(2)	FDI stock growth rate (FDIRate)	-0.144	1.000			
(3)	Embodied spillover growth rate (dSEofSE)	0.379	0.037	1.000		
(4)	Embodied spillover from imports growth rate (dSEFofSEF)	0.301	0.038	na	1.000	
(5)	Disembodied spillover growth rate (dSDofSD)	0.193	-0.008	0.118	0.120	1.000

Note: na is non-applicable since these variables are not analyzed in the same model.

Thailand

The dataset for Thailand covers the period from 2010 to 2013, the years which the subsets of data overlap. As that of Korea, the IO data for Thailand comes from the Asian Development Bank, which provides value-added and capital stock values required to calculate total factor productivity (TFP) and the total and foreign intermediate input goods necessary for the IO matrices. Inward FDI flows and FDI position (stock) are also from the Bank of Thailand. The R&D expenditure data for Thailand is taken from STI Office R&D 2017 Survey data. To calculate the wage-capital demand share, wage and value added data are taken from the national accounts data for 2010, the latest year available. Patent counts are taken from the Department of Intellectual Property, Ministry of Commerce.

Labor statistics are gathered by the National Statistics Office but the reported statistics vary depending on the level of aggregation. The broad sectors are available from the Bank of Thailand. The labor statistics at the manufacturing sectors are taken from the UNIDO INDSTAT2 database. Thus, the analysis is performed on the manufacturing sectors with the broad sectors, comprising all economic sectors, and without, manufacturing sectors only.

Endogeneity can cause problems for econometric studies through omitted variables, collinearity, and issues. While not all endogeneity can be excluded, multicollinearity of the variables is tested for. The descriptive statistics and correlation matrices are provided for all economic and only manufacturing sectors in Thailand (tables 2-8–2-10). Multicollinearity is expected from products of variables (see spillover definitions in the next subsection) and can be ignored if they are not correlated (Allison, 2012). Correlation of less than 60% suggests that collinearity is not a problem.

Table 2-8: Descriptive statistics, all economic sectors, Thailand 2010-2013

Variable		Mean	Std. Dev.	Min	Max	Obs.
dTFP	overall	0.080	0.257	-1.373	0.454	N = 57
	between		0.120	-0.342	0.196	n = 19
	within		0.228	-0.951	0.629	T = 3
FDIRate	overall	0.045	0.074	-0.123	0.275	N = 57
	between		0.047	-0.033	0.153	n = 19
	within		0.058	-0.112	0.209	T = 3
dSEofSE	overall	0.311	0.296	-0.484	1.000	N = 57
	between		0.223	-0.119	0.740	n = 19
	within		0.199	-0.235	1.022	T = 3
dSEFofSEF	overall	0.320	0.300	-0.254	1.000	N = 57
	between		0.220	-0.126	0.739	n = 19
	within		0.207	-0.136	1.099	T = 3
dSDofSD	overall	-0.098	0.950	-5.355	0.690	N = 57
	between		0.367	-1.500	0.095	n = 19
	within		0.879	-3.953	2.004	T = 3

Table 2-9: Descriptive statistics, manufacturing sectors, Thailand 2010-2013

Variable		Mean	Std. Dev.	Min	Max	Obs.
dTFP	overall	0.066	0.289	-1.373	0.454	N = 42
	between		0.136	-0.342	0.196	n = 14
	within		0.256	-0.965	0.615	T = 3
FDIRate	overall	0.047	0.070	-0.069	0.275	N = 42
	between		0.049	0.000	0.153	n = 14
	within		0.052	-0.110	0.174	T = 3
dSEofSE	overall	0.267	0.239	-0.484	0.776	N = 42
	between		0.182	-0.119	0.623	n = 14
	within		0.160	-0.279	0.650	T = 3
dSEFofSEF	overall	0.283	0.238	-0.254	0.767	N = 42
	between		0.179	-0.126	0.635	n = 14
	within		0.162	-0.089	0.656	T = 3
dSDofSD	overall	-0.116	1.019	-5.355	0.690	N = 42
	between		0.414	-1.500	0.095	n = 14
	within		0.935	-3.971	1.986	T = 3

Table 2-10: Correlation matrix, all economic sectors, Thailand 2010-2013

		(1)	(2)	(3)	(4)	(5)
(1)	Change in productivity (dTFP)	1.000				
(2)	FDI stock growth rate (FDIRate)	0.226	1.000			
(3)	Embodied spillover growth rate (dSEofSE)	0.331	0.248	1.000		
(4)	Embodied spillover from imports growth rate (dSEFofSEF)	0.156	0.238	na	1.000	
(5)	Disembodied spillover growth rate (dSDofSD)	-0.001	0.214	0.207	0.278	1.000

Note: na is non-applicable since these variables are not analyzed in the same model.

Table 2-11: Correlation matrix, manufacturing sectors, Thailand 2010-2013

		(1)	(2)	(3)	(4)	(5)
(1)	Change in productivity (dTFP)	1.000				
(2)	FDI stock growth rate (FDIRate)	0.262	1.000			
(3)	Embodied spillover growth rate (dSEofSE)	0.407	0.128	1.000		
(4)	Embodied spillover from imports growth rate (dSEFofSEF)	0.143	0.058	n/a	1.000	
(5)	Disembodied spillover growth rate (dSDofSD)	-0.055	0.169	0.166	0.269	1.000

Note: na is non-applicable since these variables are not analyzed in the same model.

2.3.3. Variables

The dependent variable used consider the absolute change in productivity without considering the scale differences between industries. The independent variables, however, remove scale differences by using the rates of change because the variable units vary between measures.

Productivity: TFP growth

The dependent variable of productivity is represented by TFP growth. TFP growth, $dTFP_i^t$, for industry *i* in period *t* is calculated using the logarithmic form of the Cobb-Douglass production equation

$$TFP_i^t = lnY_i^t - \propto_i^t \left(lnL_i^t\right) - (1 - \propto_i^t)(lnK_i^t) \quad (5)$$

Thus, the change in total factor productivity, $dTFP_i^t$, in industry *i* for time *t* is

$$dTFP_i^t = TFP_i^t - TFP_i^{t-1}$$
$$= lnY_i^t - lnY_i^{t-1} - \propto_i^t \left(lnL_i^t - lnL_i^{t-1}\right) - \left(1 - \propto_i^t\right)\left(lnK_i^t - lnK_i^{t-1}\right) \quad (6)$$

where lnY_i^t, lnL_i^t, lnK_i^t, and $\propto_i^t$ are value-added, employees, fixed capital, and ratio between labor and value-added, respectively. Due to limited data availability and common practice, the ratio $\propto$ is kept constant, using the labor and value added values from national account data of each country in 2010.

The results of the calculation for TFP growth are provided in table 2-13.

Technology transfer: Inward FDI

Technology transfer is measured by inward FDI. The $FDIRate_j^t$ is calculated by using the following equation

$$FDIRate_j^t = \frac{FDIFlow_i^t}{FDIStock_i^t} \quad (7)$$

where $FDIFlow_i^t$is the value of inward FDI and $FDIStock_i^t$is the FDI position in industry, *i*, in year, *t*.

Innovation activity: R&D stock

R&D activity is a primary source of innovation capabilities that can be measured. Industrial sector R&D expenditures measure the investment in R&D activity and is used as a proxy for R&D activity.

R&D stock is calculated using the equation

$$RS_j^t = (1 - \delta)\, RS_i^{t-1} + RS_i^t \quad (7)$$

whereRS_j^t is the R&D investment of industry, *i*, in year, *t*.

Embodied knowledge flows

R&D activity within a sector leads to spillover effects through embodied goods. The embodied knowledge that flows within and between sectors is measured by the trade of intermediate goods that are produced and used by industrial sectors.

Embodied knowledge flows for

$$SE_j^t = \sum_{i=1}^{n} b_{ij}^t\, RS_j^t \quad (8)$$

whereRS_j^t is the R&D investment of industry, *i*, in year, *t*.

The rate of change of embodied flows, SE_j^t, is calculated as

$$dSEofSE_j^t = \frac{SE_j^t - SE_j^{t-1}}{SE_j^{t-1}} \tag{9}$$

The IO matrix for intermediate goods is constructed using overall interindustry trade of intermediate goods, *IO*, and interindustry trade of imported intermediate goods, *IOF*.

Disembodied knowledge flows

R&D activity can also produce knowledge accumulation through disembodied knowledge flows through the patenting of technologies. Since the value of each patent has a probability of flowing from one sector into another, the IO matrix for disembodied knowledge flows can also be calculated.

Disembodied knowledge flows to industry *j*, SD_j^t, are represented by

$$SD_j^t = \sum_{i=1}^{n} c_{ij}^t \, RS_j^t \tag{10}$$

where the disembodied knowledge flow coefficient, c_{ij}^t, is the weighted value of knowledge flows from R&D activities, RS_j^t, in time, *t*.

The rate of change of embodied knowledge flows, SE_j^t, is calculated as

$$dSDofSD_j^t = \frac{SD_j^t - SD_j^{t-1}}{SD_j^{t-1}} \tag{11}$$

Industry and time dummies

The panel data is modeled using dummy variables for industry classification and year.

Table 2-12: TFP growth by industry

Sector	Korea					Thailand		
	2011	2012	2013	2014	2015	2011	2012	2013
AGR	0.187	0.024	0.088	-1.354	1.365	0.255	0.080	-0.010
MIN	0.238	-0.113	0.128	1.450	-2.018	0.239	0.157	0.009
FDP	0.208	0.000	0.238	-4.483	4.597	-0.137	0.192	0.054
TPL	0.243	0.107	0.079	-6.739	6.661	-0.337	0.206	0.057
LTH	0.271	0.961	-0.274	-4.902	4.703	-0.253	0.169	0.049
WPP	0.115	-0.002	0.133	-4.082	4.087	0.232	0.361	0.129
PUB	0.166	0.041	0.116	-6.949	6.942	0.035	0.330	0.016
CRP	0.851	0.061	0.028	-4.788	4.462	-1.373	0.141	0.207
CHM	0.320	-0.007	0.081	-12.749	12.800	0.025	0.454	-0.141
RUB	0.033	-0.015	0.087	-4.229	4.326	-0.028	0.204	0.057
NMT	0.197	-0.131	0.073	-2.477	2.495	-0.036	0.338	0.037
BMT	0.287	-0.017	-0.061	-3.879	3.901	0.221	0.293	0.046
MCH	0.289	0.052	0.082	-4.873	4.974	0.010	0.336	0.036
ELM	0.100	0.084	0.117	-8.116	8.116	-0.256	0.341	0.027
TRN	0.288	0.043	0.047	-6.060	6.074	0.118	0.337	0.063
MNF	0.158	-0.028	0.133	-4.480	4.723	-0.009	0.302	0.056
EGW	0.216	0.074	0.242	-2.670	3.406	0.332	-0.021	0.143
CST	0.029	-0.031	0.122	-2.385	2.643	-0.075	0.162	0.022
SVC	0.155	0.050	0.121	-2.791	2.887	0.374	0.087	0.037

Source: ADB IO data. Calculated by author

2.3.4. Model

The change in industrial sector total factor productivity, *dTFP*, is the dependent variable for all estimations. The main independent variables are calculated as rates of change. The estimation model equations (10-13) are modeled after Hwang and Lee (2010).

The estimation model for technology transfer is

$$dTFP_j^t = \lambda_j^{TT} + \phi_j^{TT}\left(\frac{dFDI_j^t}{FDI_j^t}\right) + \varepsilon_j^{TT} \tag{12}$$

where the change in FDI is the inflow of FDI is *dFDI*, and the total FDI stock is *FDI* for year *t*.

The effects of R&D activity depend on the effects based on the type of knowledge flow. The estimation model for embodied knowledge flows is

$$dTFP_j^t = \lambda_j^{E} + \phi_j^{E}\left(\frac{dSE_j^t}{SE_j^t}\right) + \varepsilon_j^{E} \tag{14}$$

where the change in embodied knowledge flows is *dSE* is divided by the total embodied spillover is *SE* in sector *j* for year *t*.

The estimation model for disembodied knowledge flows is

$$dTFP_j^t = \lambda_j^{D} + \phi_j^{D}\left(\frac{dSD_j^t}{SD_j^t}\right) + \varepsilon_j^{D} \tag{15}$$

where the change in disembodied knowledge spillover is *dSD* is divided by the total disembodied spillover is *SD* in sector *j* for year *t*.

2.4. Empirical results

2.4.1. Korea

When using panel data, the Hausman test is used to test for unobserved variables effects related to the industries. The results of the Hausman test cannot reject the random effects estimator for the Korean panel data, so random effects are used. The results are reported along with the results of the regression estimations (tables 2-15–2-18) and suggest the use of the random effects model, which is consistent and efficient.

The results of the analysis show that productivity growth in Korean industries is dependent on its innovation capabilities. The results using the total intermediate goods IO matrix are presented first (tables 2-15 and 2-16). The effect of technology transfer, *FDIRate*, on industrial sector productivity is negative in the models it appears, (1), (5), (6), and (7) when considering both datasets for all economic and only manufacturing sectors. The impact is significant when the effects of embodied knowledge flows are included when estimating all economic sectors in models (5) and (7).

The effect of industrial sector R&D activity is observed through the spillover effects through the two terms that are based on R&D activity, embodied and disembodied knowledge spillover, *dSEofSE* and *dSDofSD*, respectively. The coefficients are positive for both. Moreover, since *FDIRate* is negative, the innovation-based technology flows are the main sources of productivity growth for Korean industries. The impact of the spillover variables are higher when estimating across manufacturing sectors. The embodied knowledge flows, *dSEofSE*, are significantly positive in all models and sectors. The average change in knowledge accumulation from disembodied knowledge flows, *dSDofSD*, is not significant but has a stronger effect on productivity than technology transfer and embodied knowledge flows. In model (7) for all economic sectors (table 2-15), the coefficient of disembodied knowledge flows, 4.829, is not significant but greater than the coefficients for technology transfer, -1.328, and embodied knowledge flows, 0.743. Thus, knowledge flows from embodied channels drive productivity growth through innovation capabilities in all sectors.

When the embodied knowledge flows from imports, *dSEFofSEF*. are considered (tables 2-17 and 2-18), a slightly different picture emerges when examining all economic and only manufacturing sectors. The negative effects of technology transfer are slightly smaller across sectors on average but not significant when considering imported intermediate goods, in models (5) and (7) compared with (10) and (11). The embodied spillover effect on productivity is significant for all economic sectors and increases from 0.743 to 0.887 when imports are considered, but among manufacturing sectors, it increases from 0.831 and 0.847 when imports are considered. Thus, embodied knowledge channels are significantly stronger in manufacturing sectors.

Table 2-13: All sectors, Korea 2011-2015

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FDIRate	-1.189				-1.350*	-1.171	-1.328*
	(0.835)				(0.792)	(0.826)	(0.788)
dSEofSE		0.759***		0.720***	0.782***		0.743***
		(0.229)		(0.229)	(0.227)		(0.227)
dSDofSD			6.216*	4.941		6.154*	4.829
			(3.569)	(3.434)		(3.550)	(3.401)
Constant	0.187	0.169	-0.470	-0.273	0.293	-0.360	-0.142
	(0.359)	(0.336)	(0.471)	(0.454)	(0.341)	(0.475)	(0.457)
Industry & year dummies	Y	Y	Y	Y	Y	Y	Y
	RE	RE	RE	RE	RE	RE	RE
Hausman	0.69	0.56	0.00	0.48	4.83	0.62	4.38
(p-value)	(0.406)	(0.453)	(0.963)	(0.788)	(0.089)	(0.732)	(0.224)
R-squared within	0.033	0.121	0.032	0.138	0.186	0.061	0.196
Obs	95	95	95	95	95	95	95
Sectors	19	19	19	19	19	19	19

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 2-14: Manufacturing sectors, Korea 2011-2015

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FDIRate	-1.158				-1.271	-1.145	-1.256
	(0.964)				(0.895)	(0.953)	(0.890)
dSEofSE		0.915***		0.873***	0.929***		0.887***
		(0.271)		(0.271)	(0.269)		(0.270)
dSDofSD			7.451	5.806		7.405	5.729
			(4.598)	(4.342)		(4.583)	(4.310)
Constant	0.206	0.215	-0.584	-0.309	0.355	-0.456	-0.164
	(0.477)	(0.437)	(0.617)	(0.585)	(0.445)	(0.625)	(0.590)
Industry & year dummies	Y	Y	Y	Y	Y	Y	Y
	RE	RE	RE	RE	RE	RE	RE
Hausman	0.48	0.65	0.00	0.55	4.53	0.44	4.08
(p-value)	(0.487)	(0.419)	(0.958)	(0.761)	(0.104)	(0.804)	(0.253)
R-squared within	0.032	0.166	0.038	0.184	0.231	0.0656	0.242
Observations	70	70	70	70	70	70	70
Number of ISIC	14	14	14	14	14	14	14

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 2-15: Imported intermediate goods, all sectors, Korea 2011-2015

	(8)	(9)	(10)	(11)
FDIRate			-1.264	-1.245
			(0.799)	(0.795)
dSEFofSEF	0.869***	0.817***	0.883***	0.831***
	(0.286)	(0.286)	(0.283)	(0.284)
dSDofSD		4.936		4.848
		(3.469)		(3.442)
Constant	0.107	-0.332	0.221	-0.212
	(0.338)	(0.457)	(0.343)	(0.459)
Industry & year dummies	Y	Y	Y	Y
	RE	RE	RE	RE
Hausman	0.47	0.38	4.30	3.85
(p-value)	(0.491)	(0.825)	(0.117)	(0.279)
R-squared within	0.104	0.121	0.163	0.173
Observations	95	95	95	95
Number of ISIC	19	19	19	19

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 2-16: Imported intermediate goods, manufacturing sectors, Korea 2011-2015

	(8)	(9)	(10)	(11)
FDIRate			-1.251	-1.235
			(0.924)	(0.918)
dSEFofSEF	0.885***	0.829**	0.902***	0.847**
	(0.339)	(0.340)	(0.338)	(0.338)
dSDofSD		6.146		6.069
		(4.471)		(4.445)
Constant	0.141	-0.411	0.278	-0.269
	(0.449)	(0.600)	(0.458)	(0.606)
Industry & year dummies	Y	Y	Y	Y
	RE	RE	RE	RE
Hausman	0.36	0.28	3.25	2.88
(p-value)	(0.549)	(0.869)	(0.197)	(0.411)
R-squared within	0.105	0.126	0.165	0.179
Observations	70	70	70	70
Number of ISIC	14	14	14	14

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

2.4.1. Thailand

The Hausman test is used again to test whether there may be any unobserved effects of the industries. The Hausman test suggest the use of random effects model for most models considering all sectors, except for models (3), (8), and (10). Since the main model that includes all variables, models (7) and (11), suggests random effects, the results for random effects are reported throughout (tables 2-19–2-22). The data is also separated into overall intermediate goods (tables 2-19 and 2-20) and imported intermediate goods (tables 2-21 and 2-22).

The findings of the analysis show that productivity growth in Thailand is dependent on different technological capabilities than Korea. Technology transfer, *FDIRate*, affects productivity growth, *dTFP*, positively in all models. The difference of impact of technology transfer, *FDIRate*, between general and imported intermediate inputs increases across all and manufacturing sectors. The effect of technology transfer is higher in manufacturing when both overall intermediate goods, *dSEofSE* (tables 2-19 and 2-20), and imported intermediate goods, *dSEFofSEF* (tables 2-21 and 2-22), are considered. In the main models (7) and (11), the coefficient value for technology transfer in manufacturing using both types of intermediate goods have higher coefficients, 0.976 and 1.137, than when non-manufacturing sectors are included, 0.591 and 0.737. The impact is significant when all variables are included, models (7) and (11).

When analyzing overall intermediate goods, *FDIRate* is often significant when embodied knowledge flows are not included in the estimation, models (1) and (6), and (7) when considering manufacturing sectors.

Technology transfer is more likely to be significant in manufacturing sectors. Moreover, when technology transfer is significant, it is significant at the 1% level, whereas embodied knowledge flows are significant at the 0.1% level. Thus, technology transfer through FDI is likely to gain its influence through effects from embodied knowledge flows, when the variable is omitted.

When considering the knowledge flows that are related to innovation activities embodied and disembodied knowledge flows, *dSEofSE* and *dSDofSD* respectively, the driver of productivity is embodied knowledge flows. Disembodied knowledge accumulation has a negative but not significant effect on Thai industrial sectors in all models. Embodied knowledge accumulation is positive in all models. The significance increases from the 5% level to 1% level when considering manufacturing use of total intermediate goods, in model (7). It is significant when overall intermediate goods are considered. Thus, it is not significant when imported goods are considered.

Overall, productivity growth is driven by technology transfer and embodied knowledge accumulation, not disembodied knowledge accumulation. The main source of productivity in Thai industrial sectors, however, is technology transfer. When considering total intermediate inputs, the absolute value of the coefficients for *FDIRate* is greater than the coefficients for *dSEofSE* and *dSDofSD* across all sectors and in manufacturing sectors. Between the innovation-related variables, embodied knowledge flows dominates disembodied knowledge flows.

Table 2-17: All sectors, Thailand 2011-2013

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FDIRate	0.782*				0.531	0.820*	0.591
	(0.454)				(0.453)	(0.469)	(0.461)
dSEofSE		0.287***		0.300***	0.254**		0.268**
		(0.110)		(0.114)	(0.114)		(0.116)
dSDofSD			-0.000	-0.019		-0.014	-0.027
			(0.036)	(0.035)		(0.037)	(0.036)
Constant	0.045	-0.009	0.080**	-0.015	-0.023	0.042	-0.033
	(0.039)	(0.047)	(0.035)	(0.049)	(0.048)	(0.040)	(0.050)
Industry & year dummy	Y	Y	Y	Y	Y	Y	Y
	RE	RE	RE	RE	RE	RE	RE
Hausman	0.00	0.35	0.01	0.71	0.24	0.10	0.57
(p-value)	(0.966)	(0.554)	(0.916)	(0.702)	(0.888)	(0.954)	(0.904)
R-squared within	0.042	0.104	0.000	0.120	0.109	0.047	0.130
Observations	57	57	57	57	57	57	57
Number of ISIC	19	19	19	19	19	19	19

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 2-18: Manufacturing sectors, Thailand 2011-2013

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FDIRate	1.076*				0.876	1.146*	0.976*
	(0.625)				(0.588)	(0.639)	(0.593)
dSEofSE		0.491***		0.516***	0.458***		0.487***
		(0.174)		(0.177)	(0.173)		(0.174)
dSDofSD			-0.016	-0.036		-0.029	-0.046
			(0.045)	(0.042)		(0.044)	(0.041)
Constant	0.015	-0.065	0.064	-0.075	-0.097	0.009	-0.115*
	(0.053)	(0.062)	(0.045)	(0.064)	(0.065)	(0.054)	(0.067)
Industry & year dummy	Y	Y	Y	Y	Y	Y	Y
	RE	RE	RE	RE	RE	RE	RE
Hausman	0.19	1.17	0.05	2.23	0.71	0.50	1.86
(p-value)	(0.663)	(0.280)	(0.817)	(0.329)	(0.703)	(0.778)	(0.602)
R-squared within	0.076	0.203	0.007	0.252	0.221	0.101	0.285
Observations	42	42	42	42	42	42	42
Number of ISIC	14	14	14	14	14	14	14

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 2-19: Imported intermediate goods, all sectors, Thailand 2011-2013

	(8)	(9)	(10)	(11)
FDIRate			0.693	0.737
			(0.469)	(0.478)
dSEFofSEF	0.134	0.145	0.093	0.110
	(0.114)	(0.120)	(0.116)	(0.121)
dSDofSD		-0.013		-0.022
		(0.038)		(0.038)
Constant	0.037	0.033	0.019	0.010
	(0.050)	(0.052)	(0.051)	(0.054)
Industry & year dummies	Y	Y	Y	Y
	RE	RE	RE	RE
Hausman	0.01	0.12	0.01	0.13
(p-value)	(0.906)	(0.941)	(0.995)	(0.988)
R-squared within	0.018	0.024	0.046	0.057
Observations	57	57	57	57
Number of ISIC	14	14	14	14

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 2-20: Imported intermediate goods, manufacturing sectors, Thailand 2011-2013

	(8)	(9)	(10)	(11)
FDIRate			1.045*	1.137*
			(0.629)	(0.638)
dSEFofSEF	0.173	0.206	0.155	0.201
	(0.189)	(0.198)	(0.186)	(0.193)
dSDofSD		-0.029		-0.042
		(0.046)		(0.046)
Constant	0.017	0.005	-0.027	-0.049
	(0.070)	(0.073)	(0.073)	(0.077)
Industry & year dummies	Y	Y	Y	Y
	RE	RE	RE	RE
Hausman	0.16	0.61	0.12	0.77
(p-value)	(0.689)	(0.736)	(0.943)	(0.857)
R-squared within	0.028	0.058	0.088	0.136
Observations	42	42	42	42
Number of ISIC	14	14	14	14

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

2.5. Sensitivity analysis

The regression models may be sensitive to the differences in the scales of the variables. Therefore, lagged values of total factor productivity, *TFP*, and research stock, *RS*, are considered as controls to mitigate the impact of these differences. Panel regressions of the full model are estimated including the lagged variables (table 2-23).

The results for Korea are consistent with the previous models. Embodied knowledge flows are significant at 1% when including lagged values of *TFP* and *RS*. The FDI rate, *FDIRate*, is negative across the models and significant when the lagged value of *TFP* is included, in model (12), for all economic sectors considering total intermediate inputs of table 2-23. Embodied knowledge remains the only significant variable across all models. Disembodied knowledge flows is not significant but has a higher average effect on Korean industries.

The results for Thailand, however, suggest that effects of the different forms of knowledge flows are less consistent when lagged effects of *TFP* and *RS* are included. Technology transfer becomes positive when considering manufacturing sectors. Embodied knowledge flows remain positive but are no longer significant in any model. Rather, disembodied knowledge flows become significant across all models. This suggests that the main results are driven by scale effects of productivity and research stock in Thai industrial sectors. Moreover, the effects of all of the variables are lower in manufacturing in all models, suggesting that the absorptive capabilities are weaker in manufacturing.

Table 2-21: Sensitivity analysis including lagged variables, Korea

	All sectors			Manufacturing		
	(12)	(13)	(14)	(12)	(13)	(14)
FDIRate	-1.516*	-1.365	-1.387	-1.352	-1.277	-1.094
	(0.855)	(0.955)	(0.861)	(0.903)	(1.084)	(0.895)
dSEofSE	0.759***	0.756***	0.756***	0.841***	0.902***	0.823***
	(0.231)	(0.256)	(0.231)	(0.257)	(0.304)	(0.252)
dSDofSD	4.968	7.130	4.949	4.664	8.599	4.364
	(4.234)	(4.652)	(4.226)	(5.024)	(5.876)	(4.919)
L.TFP	-0.328***		-0.351***	-0.518***		-0.593***
	(0.082)		(0.084)	(0.114)		(0.119)
L.RS		0.000	0.000		0.000	0.000*
		(0.000)	(0.000)		(0.000)	(0.000)
Constant	5.541***	-0.157	5.735***	8.496***	-0.169	9.302***
	(1.491)	(0.551)	(1.498)	(1.978)	(0.724)	(1.986)
Industry & year dummy	Y	Y	Y	Y	Y	Y
R-squared within	0.505	0.211	0.519	0.627	0.260	0.645
Observations	76	76	76	56	56	56
Number of ISIC	19	19	19	14	14	14

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 2-22: Sensitivity analysis including lagged TFP variable, all sectors, Thailand

	All sectors			Manufacturing		
	(12)	(13)	(14)	(12)	(13)	(14)
FDIRate	-0.237	-0.088	-0.289	0.055	0.071	0.063
	(0.300)	(0.279)	(0.313)	(0.356)	(0.360)	(0.374)
dSEofSE	0.182	0.085	0.192	0.172	0.173	0.173
	(0.120)	(0.091)	(0.124)	(0.118)	(0.119)	(0.121)
dSDofSD	0.070***	0.067***	0.077***	0.062***	0.061**	0.061**
	(0.021)	(0.023)	(0.024)	(0.023)	(0.025)	(0.026)
L.TFP	-0.005		-0.005	-0.001		-0.001
	(0.007)		(0.008)	(0.007)		(0.007)
L.RS		0.000	0.000		-0.000	-0.000
		(0.000)	(0.000)		(0.000)	(0.000)
Constant	0.200*	0.133***	0.185	0.161	0.150***	0.165
	(0.118)	(0.035)	(0.127)	(0.106)	(0.047)	(0.116)
Industry & year dummy	Y	Y	Y	Y	Y	Y
R-squared within	0.422	0.369	0.422	0.465	0.465	0.467
Observations	38	38	38	28	28	28
Number of ISIC	19	19	19	14	14	14

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

2.6. Discussion

The findings of the analysis in the previous section show a stark difference between the sources of productivity growth in Korea and Thailand. The sources of productivity growth in Korea are from innovation capabilities that rely on R&D activity rather than production capabilities. In fact, the technology transfer that occurs in the Korean economy has a negative impact on the productivity across economic and manufacturing sectors in Korea. This may suggest that inward FDI is not used to increase production in Korea. Other motivations may include the use of inward FDI by foreign firms to access Korean technology. Instead, productivity growth in Korea is driven by R&D activity and its related spillovers. While the most consistent source of productivity growth across sectors is embodied knowledge spillover, disembodied knowledge spillover still has a positive, larger impact on productivity growth, suggesting that certain industries drive the disembodied knowledge accumulation in the country. Since the findings for Korean industrial sectors are robust, the implications for Korea are that it may consider improving the effects of inward FDI and the disembodied knowledge flows on productivity in underperforming industrial sectors. Since inward FDI has a negative effect on productivity, improving domestic source of financing may lessen the dependence on foreign sources.

In contrast, the sources of productivity growth in Thailand seem to be driven by production-enhancing technology transfer and knowledge accumulation through embodied knowledge flows, which are both significantly positive at first glance. When the effects of embodied knowledge flows are controlled for, however, the significance of technology transfer is only maintained in manufacturing sectors. Therefore, inward FDI in non-manufacturing sectors may be directed towards more productivity enhancing activities. Moreover, while not significant, the disembodied knowledge flows also have a negative effect overall.

When the scale effects of TFP and research stock are controlled for in the industrial sectors of Thailand, however, the impact of the different types of knowledge flows change. Technology transfer is no longer a harmless form of knowledge flow. When considering all industrial sectors, technology transfer has an overall negative effect on productivity. More importantly, the change in disembodied knowledge accumulation becomes significantly positive.

The differences between the sources of productivity growth in Korea and Thailand are quite distinct. The industrial sectors in Korea derive their productivity growth from innovation capabilities through knowledge accumulation of embodied knowledge flows. The effects of knowledge accumulation requires more in depth analysis. On the whole, Thailand seems to significantly derive its productivity growth from technology transfer and accumulation of embodied knowledge flows to increase production capabilities, especially in the manufacturing sectors. Yet, the embodied knowledge flows are the only consistently significant source of productivity growth. Furthermore, the effects of disembodied knowledge flows are quite important to understand. While the accumulation of disembodied knowledge seems to have a negative effect on productivity, sensitivity analysis suggests that it in fact significantly drives productivity growth rather the other channels of knowledge. Thus, the effects of technology transfer and knowledge accumulation through embodied knowledge flows is dependent on the scale of research stock.

The implications for Thailand may be more difficult to untangle. First, the dependence on inward FDI is difficult to recognize because it can appear to have a positive effect on industrial sector productivity. The production capabilities gained through inward FDI suggests that improvements to the financialization of the industry may lessen the dependence on foreign investment. Outward FDI may provide an alternative opportunity to transfer technology where domestic sources are deficient. Second, the goal of improving the innovation capabilities of the economy to increase productivity growth in the economy is also difficult to sort because they are tied to manufacturing and trade structures. Learning must be improved to accelerate the knowledge accumulation effects of R&D activities. Embodied knowledge flows are already effective at generating knowledge accumulation for productivity growth overall, but this is dependent on the current scales of TFP and research stocks in the current industrial structure. Strengthening the domestic supplier base is a way to resolve two implications from the results. The effects of embodied knowledge flows are not robust. Therefore, firms need to improve the knowledge absorption from embodied knowledge. Also, since the effects of knowledge flows are weaker for imported goods, another good place to start would be to targets domestic sources of intermediate goods. In other words, policies should improve the domestic supplier base. Improving domestic production of intermediate goods should generate knowledge accumulation since foreign trade barriers will not be an issue. Since knowledge accumulation through disembodied knowledge channels are significant under sensitivity analysis, increasing R&D intensity should improve knowledge accumulation through patenting. The general implication is that the innovation capabilities that seem to exist through technology transfer and embodied knowledge flows, but these are aligned with the import and production schemes within in the economy. When sensitivity to the scales of TFP and research stock are controlled for, a different picture emerges. Implying that the import and production schemes overshadow the underlying knowledge accumulation.

The main findings of this chapter are that productivity growth in Korea is consistently innovation-driven, deriving growth through industrial sector R&D activity and spillovers through embodied knowledge, but innovation development policies in Thailand are more complicated. The limitation of this study is that it does not identify the underlying determinants of innovation capabilities that drive industrial sector productivity growth. Thus, further research is suggested to understand the determinants.

The next chapter considers how the change in knowledge accumulation and attempts to identify the underlying causes.

Chapter 3.

Capability development patterns and transition strategy at the auto sector in Korea and Thailand

3.1. Introduction

The automobile industry provides a comprehensive model of an industrial sector to examine for its characteristics and its appeal for developing countries. The sector is characterized as a mature industry with long product lifecycles, complex supplier networks, and broad set of technologies, requiring implementation and innovation capabilities. This categorization, however, is changing. The industry is experiencing a “revolution” as new technologies and markets emerged, shifting expectations (Freyssenet, 2009). Yet, the automobile sector is still a large industry that is dominated by advanced countries; the leading automakers are from Germany, Japan, and the United States. Many developing countries have also made the attempt to enter the automobile sector through industrial development policy, e.g. Argentina, Malaysia, Mexico, South Africa, and Turkey. Few, however, have been successful at developing an innovation-driven auto industry. South Korea is only country that was a middle-income country in the middle of the twentieth century and now has a globally leading automaker. It is also one of the few middle-income countries that managed to avoid the middle-income trap.[2] Korean automakers are also known for having developed innovation capabilities resulting in patents. Therefore, this chapter examines the industrial development of the automotive sector to identify possible causes of sectoral innovation failure by comparing Korea and Thailand.

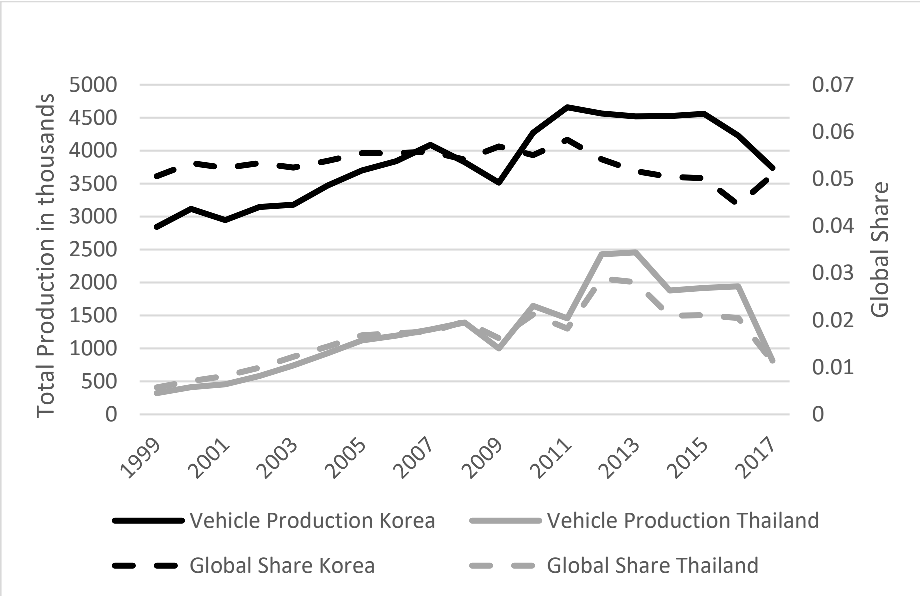
The performance of automotive sectors in Korea and Thailand are considered successes by many observers. As the exit of production in several advanced countries including Australia, the Netherlands, and Sweden attest, success in the global auto industry cannot be taken for granted. The auto industries in Korea and Thailand are compared because firms in each country entered the industry through government intervention around the same time circa 1960 but with different results. During its industrialization, South Korea famously leapfrogged technologies in targeted sectors to grow economically (Lee, 2013; Lee and Lim, 2001). In the auto sector, Hyundai Motors became the fourth largest automaker by the late 1990s. While the auto industry in Thailand later earned the moniker "Detroit of Asia," its impact on the global industry is dwarfed by that of its Korean counterpart. The difference in performance of the industries in these countries points to differences in capabilities and capability development strategy to explain the outcome.

The production outputs of the two countries have increased for decades. Recently, however, the auto industry faces many challenges, e.g. China, that

[2] While the existence of the middle-income trap is debated, the fact remains that only thirteen of more than one-hundred middle-income countries managed the transition in the last half a century.

force latecomer firms to reconsider their strategies. In recent decades, the production outputs in Korea and Thailand have slowed (figure 4) but the share of global production has dropped more precipitously in Thailand. The Korean share of the global production reached 5.8% in 2011 but managed to maintain 5.1% of the global share in 2017. Thailand, however, peaked at 2.9% of global production in 2012 and dropped to 1.1% in 2017.

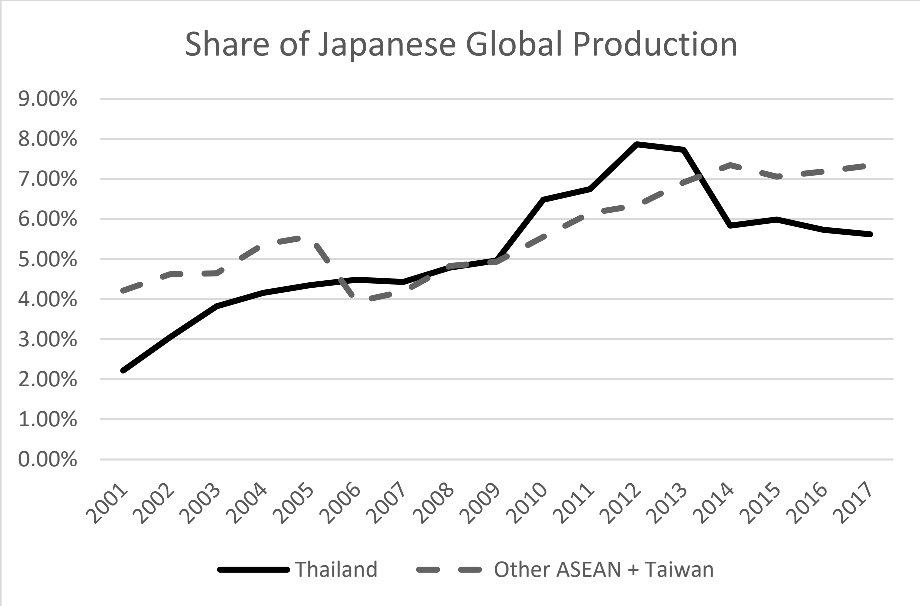
Figure 3-1: Total Vehicles & Global Share of Automobile Production



Source: Calculated from OICA Production Data

Thailand has tied its fortunes to the Japanese auto industry. Japanese automakers have built up a strong parts supplier and assembler base in Thailand. The Thai segment of Japanese auto production is higher than the global share of production (figure 5). Yet, even that base is slipping, peaking at 7.9% in 2012. The rest of the region continued to gain production share of Japanese automaker sales (figure 5), reaching 7.3% of production compared to 5.6% by Thailand in 2017.

Figure 3-2: Share of Japanese Automaker Global Sales-Production



Source: Calculated from IHS Sales Data

The outlook for the Thai auto industry is troubling and may be part of the greater middle-income trap that it seems to be facing. The auto industry is the only industrial sector that has received specific industrial policy support in Thailand (Intarakumnerd et al., 2002). Thus, transition failure at the sectoral level may lead to a national innovation system transition failure. The underlying causes still need to be identified. This chapter will provide a comparative case study of the auto industry in Korea and Thailand to determine why Korea managed to achieve sectoral innovation transition and Thailand did not.

The central question of the chapter is why has the auto sector in some middle-income countries such as Korea managed to achieve innovation transition and others such as Thailand failed to transition to innovation-driven growth? I argue that the different strategies in the industrial sector target different types of knowledge that results in different capability patterns, which has important implications for transition and transition failure.

The chapter takes a double-pronged approach: (i) describing the stylized facts that Korea, a formerly middle-income country, has escaped the middle-income trap through innovation transition and that Thailand, a middle-income country, faces a transition failure in its sectoral innovation system by using a network analysis and (ii) identifying why the transition (failure) occurred by using a comparative analysis of sectoral innovation systems framework. The framework considers the automotive sector at different levels. First, I consider the development of the innovation systems in each country. When considering the increase of innovation capabilities across industrial sectors, there should be a systematic pattern of growth. I apply statistical tests to determine whether or not this is true. Second, I look at the transportation sector of which the automotive sector is the dominant share and for which data are available. The same question is posed: is the change in innovation capabilities measured by knowledge flows increasing significantly? Finally, an innovation systems approach is applied to understand why the two countries may differ. The institutions are expected to target and develop the different aspects of the innovation system differently. Moreover, I seek out how the development of these institutions affect each other.

The main obstacle to operationalize quantitative aspects of innovation systems is that the definition of innovation transition is not well delineated by past studies. While sectoral innovation systems are used to describe the different aspects of an innovation system related to the most salient aspects of firm innovation—those that are sectoral-related (Malerba, 2002; 2004), there is no demarcation as to what makes an industrial sector innovation-driven rather than not. The complexity involved in innovation contributes to this problem. As shown in the previous chapter, however, it is possible to identify what sources of knowledge drive productivity increases. So, I begin by attempting to use network analysis to first capture the stylized fact that Korea has transitioned to innovation-driven strategies and that Thailand has not.

Once the sectoral innovation system transition or failure is made more concrete, the sectoral innovation system approach is applied to understand what the difference is in how innovation transition occurs. Previous studies on sectoral innovation systems and development have focused on catch-up (Malerba and Mani, 2009; Malerba and Nelson, 2011; Malerba et al., 2017). Yet, these studies limit the discussion to catch up and catch-up failure. Typically, transition failure is framed as the failure of growth that is linked to market failure, technological lock-in, or policy failures (Choung et al., 2016; Fagerberg, 2000; Hu and Hung, 2014). This study follows in the same tradition but attempts to identify different types of knowledge transmission within an innovation system tied to economic activities (often measured by productivity) that results in transition or failure. The previous chapter provides an empirical quantitative analysis along a similar framework.

Focusing on the transition process described by the network analysis, I review the dynamic interactions between firms and other actors in the network to determine where along the way transition is promoted or dampened along the way to development. The previous chapters considered the effects of embodied and disembodied knowledge flows of industrial sectors as a source of productivity growth within an industry. This chapter examines broader structures that affect knowledge stock—especially the production of knowledge capital—to understand how and why knowledge accumulated differently. I construct a framework by examining the literature on innovation studies and knowledge management to analyze what causes the innovation transition failure at the sectoral level in a developing country.

The next section of the chapter reviews the literature and constructs a theoretical framework to explore possible explanations for the difference in performance between the auto sectors in Korea and Thailand. In section 3.3, network analysis is used to provide a relative, quantitative comparison between the two innovation systems. In section 3.4, I explore the determinants of the difference through sectoral innovation system approach. The final section provides a summary and conclusion.

3.2. Sectoral innovation transition or failure: A theoretical framework

This section provides a review of the literature of sectoral innovation systems in developing countries and the potential causes of transition failure at the sectoral level. The theoretical framework takes a departure from previous studies by attempting to make a quantitative, if relative, definition of innovation transition and failure using network analysis.

3.2.1. Sectoral innovation systems in developing countries

While there are several different levels at which innovation systems have been analyzed, the sectoral system has the most direct impact on firms' innovation capabilities (Malerba, 2002; 2004). Different types of innovation systems approaches consider the firm as the central actor of innovation because they are the focal point of economic activity (Edquist, 1997; Lundvall, 1988; Malerba, 2002; Nelson, 1992). Innovation systems, however, have similar structures in that they consider firms networks or linkages with other actors and the institutions and policies that govern their interactions that lead to innovation (Edquist, 1997). The innovation systems approach is grounded in evolutionary economics theory that emphasizes the accumulation of knowledge through dynamic interactions (Nelson and Winter, 1982). Nonetheless, Malerba (2002) finds that firms are most directly affected by sectoral aspects of innovation systems.

> "The…tradition is about links and interdependencies and, consequently, sectoral boundaries. It stresses that the boundaries of sectors should include interdependencies and links among related industries, and that these boundaries are not fixed but change over time. Dynamic complementarities among artifacts and activities thus provide force and trigger mechanisms of growth and innovation." (Malerba, 2004, p. 14)

There are several studies of sectoral innovation systems in developing countries (Malerba and Mani, 2009; Malerba and Nelson, 2011; 2012; Malerba et al., 2017). Malerba and Mani (2009) consider several different sectors to examine the characteristics of sectoral catch-up in developing countries to contrast the difference between developed countries. First, there are many ways in which sectoral innovation systems are similar to developed countries such as the structure and purpose of different parts of the framework. High-skilled human capital is necessary for innovation-intensive sectors. Second, the findings distinguish sectoral innovation in development in several ways. Sectors in developing countries may vary in the level of catchup. Moreover, the strengths and weaknesses of the sector is dependent on national characteristics of sectoral innovation systems. Strong interdependency between industrial sectors are a source of advantage for a nation-sector. Government intervention can be beneficial or detrimental to sectoral development.

The different aspects of production and innovation are emphasized in those studies as well. Malerba and Nelson (2011) study sectoral catch-up and economic development and find successful catch-up within a nation-sector is dependent on several factors. Malerba expands this area of research in Malerba et al. (2017), which identifies how latecomers catch up within sectoral innovation systems. Economies of scale enable large countries to develop production capabilities quickly, e.g. China (Malerba and Nelson, 2011). For developing countries, catch-up in a sector is defined within the domestic market and in the global market. Product and process innovation capabilities, however, are required in for global catch-up (Malerba et al., 2017; Malerba and Nelson, 2011). The automotive industry is a scale-intensive sector that has slow-changing technology with few innovators and rarely has changes of market leadership (Breschi and Malerba, 1997) but these aspects are changing as both process and product technologies are undergoing a shift towards new market demands for energy efficiency, safety, and ICTs (Malerba and Nelson, 2011).

These past studies, however, have all focused on economic catch-up of the sectoral system. While this study distinguishes catch-up from innovation transition, catch-up is still part of the process of transition. Yet, it is not a sufficient aspect to innovation system transition that is necessary to reach high-income.

Firms and other actors develop capabilities based on their ability to learn. Learning involves the recombination of knowledge (Cohen and Levinthal, 1989; Eisenhardt and Martin, 2000), which underlines the need to accumulate knowledge. Catching up by firms within an industrial sector of a developing or latecomer country requires specific capabilities for learning or innovation. Innovation capabilities are broadly defined: "capabilities…required to adopt, adapt, and modify technologies developed elsewhere, to introduce modifications and incremental innovations and eventually generate totally new products and processes" (Malerba and Nelson, 2011, p. 1648). Catching up requires specific capabilities for learning: accessing complementary assets, absorptive capabilities, and innovation capabilities that are specific to different industrial sectors. Catching up is also supported by access to foreign sources of knowledge, coevolution and alignment of governance structures and policies.

Bell and Pavitt (1993) describe the process in which knowledge accumulation occurs in developed and developing countries. Production capabilities require technical knowledge while technological knowledge is necessary for innovation. Lall (1992) referred to these forms of knowledge as know-how and know-why. The development process is an incremental accumulation of production capabilities that transition into innovation capabilities (Kim, 1997). Lee and Kim (2009) suggest that innovation capabilities are required for sustained growth.

While firms are the central actor for economic activity, other actors in the innovation system are important for accumulation of knowledge. Universities and research institutes are sources of innovation capabilities in an SIS (Malerba, 2002). The Triple Helix Model suggests the importance of industry-university-government interactions (Ekskowitz, 2000).

Country-sector aspects of industrial organization have also been important in developing sectoral innovation. The multinational corporation also provides control over subsidiaries and knowledge through management (Kogut and Zander, 1993). Foreign carmakers operating in Thailand have been an important source of foreign knowledge and production capacity building (Intarakumnerd et al., 2014; Techakanont and Terdudomtham, 2004). Family-owned conglomerates have an impact on knowledge accumulation (Intarakumnerd et al., 2014). In examining the Korean industry, Kim and Lee (2009) find that vertical interdependencies and local demand can hamper industrial growth. Industrial organizations form networks through which knowledge bases are built within a sectoral innovation system.

Different institutions affect the ability for actors in the innovation system to learn at optimal or suboptimal levels. Organizational aspects of an industry can affect the what and how the firms in the sector learn. Hobday et al. (2004) suggest that firms can resolve the innovation dilemma by innovating along a staged-process for a developing economy to successfully transition to innovation-driven growth. Developing OEM products is a precursor to developing advanced innovations required for ODM and OBM.[3] These approaches, however, also have their limits (Ernst, 2002). Studies in economic geography focus on spatial clustering as a means to accumulate sufficient resources and efficiency to spur innovation (Cowan et al., 2004). Global value chains offer opportunities for capability development in sectoral innovation systems through transfer of knowledge but depends on supplier competence and complexity of transactions (Pietrobelli and Rabellotti, 2011).

Formal laws and policies also form institutions that affect innovation (Malerba, 2002). In some cases these policies can be misaligned and hamper the innovation in a sector (Hu and Hung, 2014). National boundaries often determine policies that affect innovation systems (Lundvall, 1992; Nelson, 1992). The interaction between sectoral and national innovation systems, however, is important for determining factors of economic development (Malerba and Nelson, 2011).

Economic development is driven by two forms of capabilities tied to tacit knowledge: technical and technological knowledge (Bell and Pavitt, 1993). Tacit and explicit knowledge may be used to produce new knowledge but tacit knowledge is necessary (Nonaka and Takeuchi, 1995). The modes of innovation determine how tacit knowledge is transformed into innovation

[3] OEM, ODM, and OBM are original equipment manufacturers, original design manufacturers, and original brand manufacturers, respectively. They differentiate levels of intellectual property ownership in production and represent technological sophistication of firms.

(Parrilli and Heras, 2016). Parrilli and Heras (2016) find that technical knowledge is formed through learning by doing, using, and interacting and technological knowledge is formed through science and technology-based innovation.

Moreover, the transmission of knowledge is affected by the motivations for motivation (Osterloh & Frey 2000; Tsai et al 2010). Government policy can mitigate risk to increase the transmission of knowledge (Kim et al 2010; Lee and Cin, 2010; Wu et al 2010). Thus, knowledge transmission can be increased by accumulating knowledge to reduce the risk of new innovations.

3.2.2. Innovation system transition or failure

Past studies on developing countries and sectoral innovation systems focus on catch-up (Malerba and Mani, 2009; Malerba and Nelson, 2011; Malerba et al., 2017). The threat of the middle-income trap, however, stems from the lack of innovation capabilities even when production capabilities are present. Thus, the middle-income trap is a result of the failure to transition to innovation-based growth. Transition capabilities are necessary to enable the transition process from middle-income to high-income level (Lee et al., 2019). Yet, these capabilities still need to be further explored. This chapter considers the effect of organizational frameworks on the process of knowledge accumulation in developing countries.

Transition failure has been given different definitions in previous studies, which should be clarified from the beginning. Transition failure is often used to describe the failure to transition from one technological paradigm or regime to another preferred paradigm or regime. For instance, Wells and Nieuwenhuis (2012) examine the transition failure as it relates to the auto industry transition away from traditional internal combustion engine technology. Choung et al. (2016) suggest that transition failure occurs as a result of inadequate policy planning, resource allocation, and poor coordination among actors. A study that is more similar in approach is one by Jaccobson and Bergek (2006), which attempts to identify innovation system weaknesses and how they might be addressed through policy intervention. Yet, this study still focuses on economic catch-up. To further clarify, the transition does not mean that production capabilities are abandoned but that sources of growth expand to include innovation-related R&D activities.

Knowledge is necessary to develop strategic assets for competitive advantage (Winter, 1987). The concept that learning is necessary for any country to develop an innovation-driven economy is widely accepted. Knowledge-driven growth is necessary for economic growth in high-income countries. Economies must accumulate knowledge through learning activities to develop differentiated capabilities that allow sustained growth in competitive environments. Countries in middle income have been able to achieve high rates of growth when in low income and lower-middle income. Yet, the rates of growth in many middle-income countries tend to slow as they reach upper-middle income levels, falling into the middle-income trap (Eichengreen et al, 2014).

3.2.3. Hypotheses

Once the knowledge networks have been modeled using the dichotomous matrices based on IO data of embodied and disembodied knowledge flows, the change in knowledge flows can be tested statistically.

First, it is necessary to confirm that Korea has a stronger sectoral innovation system than Thailand.

H1a: Korea has a sectoral innovation system that has greater embodied knowledge accumulation than Thailand.

H1b: Korea has a sectoral innovation system that has greater disembodied knowledge accumulation than Thailand.

Second, if the innovation system functions well in a country, then the knowledge flows should increase over time. I consider whether the knowledge flows through embodied and disembodied knowledge channels have grown in each country.

H2a: Embodied knowledge flows have increased over time in Korea

H2b: Disembodied knowledge flows have increased over time in Korea.

H3a: Embodied knowledge flows have increased over time in Thailand

H3b: Disembodied knowledge flows have increased over time in Thailand.

3.3. A network analysis of knowledge networks: Stylized facts of transition (failure)

To my knowledge there have not been studies that have attempted to quantify the innovation transition process. The previous chapter examined different types of knowledge flows within and between industries to understand how they change over the development stages of an economy and its innovation system. Innovation was found to be tied to embodied and disembodied knowledge spillovers at higher levels of innovation transition. This chapter attempts to quantify the difference in innovation system transition towards effective use of these knowledge flows through the change in network densities and centralities.

3.3.1. Network analysis of IO-based innovation matrices

The IO framework is shown to be the best model of the interindustry knowledge flows of an economy (DeBresson, 1996a). Leoncini et al. (1996) introduced network analysis to measure IO-based innovation spillovers. Network analysis can be used to measure properties of the intra-industry and interindustry knowledge flows (Chang and Shih, 2005; DeBresson, 1996; Leoncini et al., 1996; Montressor and Marzetti, 2009). Network density demonstrates how connected a system is. The degree centrality of an industry shows the dependency of an industry on the in-flows or out-flows of innovation from other industries. When applying network analysis, however, it is important to understand the scale and dichotomization issues that arise (Montressor and Marzetti, 2009).

Innovation systems

Although previous studies using network analysis on interindustry IO matrices referred to as technological systems, this chapter refers to the same systems as innovation systems. Innovation systems are known to rely on organizations of networked actors to accumulate knowledge that is most affected by sector level aspects (Edquist, 1997; Lundvall, 1992; Malerba, 2002). Interindustry knowledge flows have been modeled on weights applied to R&D expenditures (Griliches, 1992). Like the previous chapter, past studies use the Leoncini inverse on the trade of intermediate goods within an economy and patenting (Hwang and Lee, 2014; Jaffe, 1986; Terleckyj, 1980). Following the work of Montressor and Marzetti (2009), interindustry embodied knowledge flows are defined through the n x n matrix, **R**,

$$\boldsymbol{R} = \hat{\boldsymbol{r}}\hat{\boldsymbol{q}}^{-1}(\boldsymbol{I} - \boldsymbol{A})^{-1}\hat{\boldsymbol{y}} = \hat{\boldsymbol{r}}\boldsymbol{B} \quad (14)$$

where $\hat{r}$, $\hat{q}$, and $\hat{y}$ are the diagonal matrices of industrial sector R&D expenditures, production output, and final demand, respectively. $(\mathbf{I}\text{-}\mathbf{A})^{-1}$ is the Leontief inverse. While knowledge accumulation is typically measured by the R&D activities performed in a sector, usually proxied by R&D expenditure, the effects of the R&D activities can spill over into other industries through interindustry interactions (Grilliches, 1991).

Previous studies model disembodied knowledge spillovers in a similar fashion, using IO matrices defined by patenting activity weighted by probabilities of spillover to other industries (Hwang and Lee, 2014; Jaffe, 1986). This is represented by

$$\boldsymbol{R} = \hat{\boldsymbol{r}}\boldsymbol{C} \tag{15}$$

where **C** is an n x n matrix representing the disembodied knowledge flows of an innovation system (see previous chapter for a description of the construction of the **C** matrix).

Density

Density, δ, is a measure of the connectedness of the entire innovation system. It is calculated as a sum of the total edges between nodes using

$$\delta(t) = \frac{\sum_i \sum_{j(i \neq j)} d_{ij}(t)}{n(n-1)}, \text{ with } 0 \leq \delta(t) \leq 1 \tag{16}$$

where knowledge flows from industry *i* to industry *j*, which are nodes, and the edges, d_{ij}, are defined by a dichotomous matrix constructed by imposing a cutoff value on the knowledge flows of **R**.

Centrality

Degree centrality is a measure of the dependency or pervasiveness of an industry on spillovers form other industries. Degree centrality varies depending on whether the in-degree or out-degree is measured. In-degree and out-degree centrality are calculated by

$$c_j^{in}(t) = \sum_{i(i \neq j)} d_{ij}(t), \text{ with } 0 \neq c_j^{in}(t) \neq \text{n-1} \tag{17}$$

$$c_i^{out}(t) = \sum_{j(i \neq j)} d_{ij}(t), \text{ with } 0 \neq c_i^{out}(t) \neq \text{n-1} \tag{18}$$

Scale and dichotomization

The measure of the innovation systems depends on the scale differences between industries. How these scales are defined affect what is being measured (table 3-1). $\mathbf{R}^{unit}$ is a measure of innovation flows divided by final demand and is defined by

$$\boldsymbol{R^{unit}} = \boldsymbol{R}\,\boldsymbol{\hat{y}^{-1}} \qquad (19)$$

The unit basket of final demand, R^{basket}, removes the scale difference of final demand and is calculated by

$$\boldsymbol{R^{basket}} = \frac{\boldsymbol{1}}{\boldsymbol{i'y}}\,\boldsymbol{R} \qquad (20)$$

where $\boldsymbol{i'}$ is a unit row vector.

The normalized R, R^{norm}, removes differences in R&D intensity between sectors and is defined by

$$\boldsymbol{R^{norm}} = \frac{\boldsymbol{1}}{\boldsymbol{i'r}}\,\boldsymbol{R} \qquad (19)$$

The fourth relativization is by the innovation inputs and is defined by

$$\boldsymbol{C} = \boldsymbol{R}\,\widehat{(\boldsymbol{\iota'R})}^{-\boldsymbol{1}} \qquad (20)$$

For a discussion on how these relativizations are performed, see appendix.

Table 3-1: Rationale of the relativization procedures

		Focus of analysis	
		System	Subsystem
Relativization dimension	Economic	$\mathbf{R}^{basket}$	$\mathbf{R}^{unit}$
	Technological	$\mathbf{R}^{norm}$	C

Source: Montressor and Marzetti (2009)

3.3.2. Network density of the auto industry in Korea and Thailand

The results of the network density analysis are presented in tables 3-2–3-5. In comparing the network density of the auto industry between the countries, Korea has a higher density regardless of the relativization method used (figure 3-3). That is, the sectors in Korea are more connected through embodied knowledge than those in Thailand, even when final demand scale and R&D intensity are removed. The embodied knowledge flows are also visualized for each country in graphs in appendix A-3.

Moreover, the change over time is relatively positive in all the relative dimensions in Korea, except when analyzing the technological subsystem, using the **C** matrix (table 3-2). The change is positive for the $\mathbf{R}^{unit}$, $\mathbf{R}^{norm}$, and $\mathbf{R}^{basket}$ matrices. These matrices measure the movement of the embodied knowledge networks between 2010 and 2013 considering changes in final demand, across sectors, and production changes. The **C** matrix considers the intensity of the knowledge flows in and out of a sector. Thus, the decrease over time, suggests that the sectors have lowered their dependencies on external sectors.

Thailand, however, does not show the same pattern of development. While the $\mathbf{R}^{unit}$ and $\mathbf{R}^{norm}$ matrices suggest that the Thai innovation system has grown, it is driven by growth in overall production output rather than increases in R&D activity. The inversions in the $\mathbf{R}^{basket}$ and **C** matrices suggest that there has been uneven development of the innovation systems for embodied knowledge at the economic system and technological subsystem levels. The indexes have experienced negative change over time at different levels of cutoffs (table 3-3).

When examining the disembodied knowledge matrices, the Korean innovation system again outperforms that of Thailand. The $\mathbf{RD}^{unit}$ and **CD** matrices show a clear distance between the Korean and Thai network densities, suggesting a stronger disembodied knowledge network in Korea. When considering the change in network densities eliminating scale of R&D intensities, $\mathbf{RD}^{norm}$, Thailand has increased its network densities in sectors that are less dense, where the cutoff is lower. A narrow part of the density curve of the $\mathbf{RD}^{basket}$ matrix shows an inversion between Korea and Thailand. This suggests that a narrow part of the disembodied knowledge network saw an expansion in the period.

The disembodied knowledge networks in Korea have strengthened in the period 2010-2013. The changes of the $\mathbf{RD}^{unit}$, $\mathbf{RD}^{norm}$, and $\mathbf{RD}^{basket}$ matrices are mostly positive (table 3-4). The disembodied growth of the Korean networks has also become more connected under the relativization procedures, except under the **C** matrix. This movement, however, does not suggest a weakness of the network. Rather the sector is relatively less reliant on disembodied knowledge from other sectors.

The disembodied knowledge network in Thailand has not been wholly positive. The $\mathbf{RD}^{unit}$ and $\mathbf{RD}^{norm}$ have increased (table 3-4). The $\mathbf{RD}^{basket}$ matrix considers the knowledge flows from external sectors. Thailand has not managed to improve the economic subsystem, which suggests the improvement comes from increase in final demand and production output. This suggests that the auto sector is less reliant on inputs from other industrial sectors.

The change in the Thai innovation system based on disembodied knowledge flows shows that the Thai innovation system has grown. The growth can be seen in the increased production output, R^{unit}.

Figure 3-3: Embodied knowledge network densities of the auto industry in Korea and Thailand, 2010

Table 3-2: Index of densities of embodied knowledge matrices, Korea

	R-Unit			R-Norm			R-Basket			C		
Cutoff	2010	2013	Change	2010	2013	Change	2010	2013	Change	2010	2013	Change
1	0.973	1.000	0.027	0.973	1.000	0.027	0.973	1.000	0.027	0.973	0.973	0.000
2	0.973	1.000	0.027	0.946	0.973	0.027	0.946	0.973	0.027	0.919	0.865	-0.054
3	0.973	1.000	0.027	0.919	0.946	0.027	0.865	0.892	0.027	0.892	0.838	-0.054
4	0.973	1.000	0.027	0.730	0.757	0.027	0.703	0.730	0.027	0.811	0.757	-0.054
5	0.865	0.865	0.000	0.622	0.676	0.054	0.622	0.649	0.027	0.757	0.622	-0.135
6	0.730	0.757	0.027	0.514	0.541	0.027	0.486	0.514	0.027	0.676	0.541	-0.135
7	0.568	0.595	0.027	0.378	0.378	0.000	0.378	0.378	0.000	0.595	0.297	-0.297
8	0.378	0.514	0.135	0.216	0.216	0.000	0.216	0.216	0.000	0.459	0.081	-0.378
9	0.054	0.108	0.054	0.000	0.027	0.027	0.027	0.027	0.000	0.054	0.027	-0.027

Table 3-3: Index of densities of embodied knowledge matrices, Thailand

	R-Unit			R-Norm			R-Basket			C		
Cutoff	2010	2013	Change	2010	2013	Change	2010	2013	Change	2010	2013	Change
1	0.865	0.919	0.054	0.838	0.946	0.108	0.838	0.946	0.108	0.865	0.946	0.081
2	0.459	0.730	0.270	0.676	0.703	0.027	0.676	0.703	0.027	0.838	0.865	0.027
3	0.324	0.405	0.081	0.459	0.486	0.027	0.486	0.541	0.054	0.676	0.595	-0.081
4	0.108	0.135	0.027	0.378	0.432	0.054	0.405	0.432	0.027	0.541	0.378	-0.162
5	0.000	0.000	0.000	0.270	0.297	0.027	0.324	0.297	-0.027	0.297	0.270	-0.027
6	0.000	0.000	0.000	0.243	0.189	-0.054	0.243	0.189	-0.054	0.216	0.216	0.000
7	0.000	0.000	0.000	0.189	0.108	-0.081	0.189	0.135	-0.054	0.189	0.189	0.000
8	0.000	0.000	0.000	0.081	0.054	-0.027	0.054	0.027	-0.027	0.135	0.135	0.000
9	0.000	0.000	0.000	0.027	0.027	0.000	0.027	0.027	0.000	0.000	0.027	0.027

Table 3-4: Index of densities of disembodied knowledge matrices, Korea

	R-Unit			R-Norm			R-Basket			C		
Cutoff	2010	2013	Change	2010	2013	Change	2010	2013	Change	2010	2013	Change
1	0.973	1.000	0.027	0.973	1.000	0.027	0.946	0.973	0.027	0.973	1.000	0.027
2	0.973	1.000	0.027	0.946	0.946	0.000	0.865	0.892	0.027	0.946	0.946	0.000
3	0.973	1.000	0.027	0.622	0.649	0.027	0.730	0.757	0.027	0.892	0.838	-0.054
4	0.973	1.000	0.027	0.486	0.514	0.027	0.541	0.622	0.081	0.865	0.784	-0.081
5	0.865	0.865	0.000	0.351	0.378	0.027	0.486	0.514	0.027	0.730	0.622	-0.108
6	0.703	0.703	0.000	0.216	0.243	0.027	0.459	0.486	0.027	0.514	0.459	-0.054
7	0.568	0.595	0.027	0.054	0.108	0.054	0.351	0.405	0.054	0.459	0.270	-0.189
8	0.378	0.405	0.027	0.027	0.027	0.000	0.216	0.243	0.027	0.351	0.108	-0.243
9	0.054	0.081	0.027	0.000	0.000	0.000	0.027	0.054	0.027	0.027	0.000	-0.027

Table 3-5: Index of densities of disembodied knowledge matrices, Thailand

	R-Unit			R-Norm			R-Basket			C		
Cutoff	2010	2013	Change	2010	2013	Change	2010	2013	Change	2010	2013	Change
1	0.811	0.919	0.108	0.811	0.919	0.108	0.865	0.946	0.081	0.865	0.919	0.054
5	0.432	0.757	0.324	0.568	0.757	0.189	0.865	0.946	0.081	0.865	0.541	-0.324
9	0.189	0.514	0.324	0.541	0.757	0.216	0.838	0.865	0.027	0.811	0.297	-0.514
13	0.108	0.243	0.135	0.541	0.757	0.216	0.514	0.703	0.189	0.459	0.189	-0.270
17	0.000	0.000	0.000	0.405	0.703	0.297	0.324	0.324	0.000	0.270	0.162	-0.108
21	0.000	0.000	0.000	0.351	0.649	0.297	0.108	0.081	-0.027	0.216	0.162	-0.054
25	0.000	0.000	0.000	0.324	0.568	0.243	0.054	0.027	-0.027	0.054	0.108	0.054
29	0.000	0.000	0.000	0.216	0.459	0.243	0.027	0.027	0.000	0.027	0.081	0.054
33	0.000	0.000	0.000	0.054	0.081	0.027	0.000	0.027	0.027	0.000	0.027	0.027

3.3.3. Network centrality of the auto industry in Korea and Thailand

Comparing the network centrality of the innovation systems in Korea and Thailand, the results show the dependency on in-flows and out-flows of knowledge (figures 9-12). When considering the embodied knowledge in-flows, Korea has higher centrality measures across the different relativization methods, reflecting higher in-flows from other sectors. As measured by the **C** matrix, the change in input intensity, however, has decreased in the Korean innovation system. Thailand shows a mixed outcome. Although the overall change of the innovation system at the economic level has been positive, the underlying aspects of the innovation systems are more difficult to determine. The $\mathbf{R}^{norm}$ and $\mathbf{R}^{basket}$ matrices suggest that at several points along the innovation system, there has been decline in the spillovers of embodied knowledge.

When considering the dependency of the knowledge outflows, Korea has higher levels of dependency but less so than the inflows. This may reflect the limits of the differences of how automotive products can be used outside of the industry.

Considering the inflows of disembodied knowledge networks, Korea has a stronger dependency of disembodied knowledge when looking at the $\mathbf{R}^{unit}$ matrix. The source of this difference comes from the intensity of the inputs, **C** matrix, rather than production, $\mathbf{R}^{norm}$, where Thailand has larger effects. Another source of the difference may be concentration of the disembodied knowledge from specific industry sectors because the $\mathbf{R}^{basket}$ show the distributions crossing in the middle. The change of input intensity, **C** matrix, in

Korea seems to suggest that the auto industry is less reliant on knowledge inputs from other sectors. This may reflect the increasing technological complexity within the industry. The outflows of disembodied knowledge in the innovation systems show a somewhat similar pattern.

3.3.4. Statistical analysis of meta-network characteristics

The dichotomous matrices that are constructed for the knowledge flows are sensitive to the cutoffs that are used in their construction. Although the comparison of the different visualizations of the knowledge networks provide intuitive perspectives to understand the relative differences between the knowledge networks, a statistical analysis is applied to test the differences.

This study defines the survival function equal to the density or centrality of the matrix. The cutoff value determines the survival rate and serves as "time" value by increasing the cutoff value between the minimum and maximum to create the dichotomous matrices. As the cutoff increases, the density or centrality distribution takes the form of the non-parametric Kaplan-Meier estimator (Kaplan and Meier, 1958). Thus, the difference between curves can be tested for statistical significance using the log-rank test for equality of the distribution functions of Kaplan-Meier curves (Campbell and Swinscow, 2002).

The log-rank test is applied to the difference between the distribution curves of the knowledge flow matrices (tables 3-6–3-9). The results suggest that we must reject the hypothesis that knowledge flow matrix survival curves between Korea and Thailand are equal, except for the $\mathbf{RD}^{norm}$ and $\mathbf{RD}^{basket}$

matrices in 2010 and 2013 and the **C** matrix in 2013. The $\mathbf{RD}^{norm}$ and $\mathbf{RD}^{basket}$ matrices scale the differences of R&D and final demand respectively. Therefore, the difference between the two countries' disembodied knowledge flows is based on R&D intensity, captured in $\mathbf{RD}^{unit}$. The **C** matrix is a measure of how dependent the system is on specific sectors, which may not have strong influences on the innovation performance of the national innovation systems.

The difference in performance between the two countries across the 2010-2013 period, however, is more informative. Across all the different relativization methods, the knowledge flows in Korea change significantly each year. In Thailand, however, the change in knowledge flows is only significant for disembodied knowledge flows when scaled by final demand, $\mathbf{RD}^{basket}$.

Table 3-6: Results of log-rank test for equality of density distribution functions

Matrix network	Korea-Thailand 2010	Korea-Thailand 2013	Korea 2010-2013	Thailand 2010-2013
R-unit	19.44*** (0.000)	12.62*** (0.000)	116.84*** (0.000)	3.18 (-0.364)
R-norm	18.57*** (0.000)	15.25*** (0.000)	50.10*** (0.000)	0.65 (-0.885)
R-basket	15.06*** (0.000)	14.26*** (0.000)	47.43*** (0.000)	0.53 (-0.913)
C	14.62*** (0.000)	2.32 (-0.128)	105.22*** (0.000)	0.16 (-0.984)
RD-unit	22.31*** (0.000)	9.49*** (-0.002)	104.81*** (0.000)	7.39* (-0.061)
RD-norm	2.21 (-0.137)	0.42 (-0.515)	20.85*** (-0.001)	44.28*** (0.000)
RD-basket	0.67 (-0.414)	0.11 (-0.741)	97.53*** (0.000)	2.30 (-0.513)
CD	11.65*** (-0.001)	20.15*** (0.000)	65.53*** (0.000)	14.48*** (-0.002)

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 3-7: Results of log-rank test for equality of in-degree centrality distribution functions

Matrix network	Korea-Thailand 2010	Korea-Thailand 2013	Korea 2010-2013	Thailand 2010-2013
R-unit	41.58***	41.58***	50.4***	16.63***
	(0.000)	(0.000)	(0.000)	(0.001)
R-norm	20.02***	22.08***	1.02	0.5
	(0.000)	(0.000)	(0.796)	(0.919)
R-basket	22.97***	24.71***	2.25	0.5
	(0.000)	(0.000)	(0.522)	(0.919)
C	41.58***	36.92***	42.5***	4.34
	(0.000)	(0.000)	(0.000)	(0.227)
RD-unit	38.36***	40.1***	48.9***	6.92*
	(0.000)	(0.000)	(0.000)	(0.074)
RD-norm	0.1	0.1	1.55	0.96
	(0.753)	(0.753)	(0.672)	(0.810)
RD-basket	6.07**	10.41***	39.71***	2.8
	(0.014)	(0.001)	(0.000)	(0.424)
CD	17.43***	0.03	36.93***	22.83***
	(0.000)	(0.868)	(0.000)	(0.000)

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3-8: Results of log-rank test for equality of out-degree centrality distribution functions

Matrix network	Korea-Thailand 2010	Korea-Thailand 2013	Korea 2010-2013	Thailand 2010-2013
R-unit	37.04*** (0.000)	40.62*** (0.000)	1.46 (0.918)	0.65 (0.885)
R-norm	1.81 (0.179)	6.36** (0.012)	0.28 (0.998)	3.94 (0.268)
R-basket	1.15 (0.283)	5.38** (0.020)	0.17 (0.999)	2.29 (0.514)
C	1.14 (0.286)	1.64 (0.201)	2.06 (0.841)	1.34 (0.720)
RD-unit	33.54*** (0.000)	38.97*** (0.000)	19.1*** (0.002)	3.64 (0.303)
RD-norm	12.36*** (0.000)	15.81*** (0.000)	25.04*** (0.000)	11.91*** (0.008)
RD-basket	6.87*** (0.009)	21.59*** (0.000)	1.66 (0.894)	6.78* (0.079)
CD	1.1 (0.295)	2.59 (0.107)	6.19 (0.288)	20.63*** (0.000)

Standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

3.4. Sectoral innovation system transition (failure): A comparative analysis

3.4.1. Sectoral innovation system transition

The innovation systems approach focuses on analysis of the actors and their networks, the linkages between them, and institutions and policies that affect the creation and diffusion of knowledge between them. The sectoral innovation system approach focuses on the most salient aspects of the innovation system, those defined by the industrial sector.

The actors in the automotive industry include the firms that produce and sell automotive products. The supplier networks are hierarchically tiered according to the level of control over the production value. The branded carmaker is at the top since they provide the key technology and management aspects of the industry. The auto industry is one of the more globally-oriented production systems. The expansion of production is related to the marketing aspects, which reflect the targeting of different geographical markets as well.

Other actors in innovation systems affect innovation by providing activities that increase the knowledge base of the sector. Universities and research institutes create knowledge outputs in the form of patents and other tacit knowledge, and are thus a source of innovation capabilities (Intarakumnerd et al., 2011). Education systems also increase tacit knowledge represented by skilled human capital. Associations and consortiums are actors that also represent networks within the innovation system.

Networks and linkages between actors, however, suggest transmission of knowledge within the innovation system. This study focuses on the transmission of embodied and disembodied knowledge on one level and the inputs and outputs that are necessary to create and absorb knowledge.

Knowledge can be tacit or explicit, which determines how it can be transmitted across networks. Knowledge that can be expressed through words or pictures is explicit knowledge. Explicit knowledge can be embodied in the production of goods and production technology. Knowledge that cannot be put down cannot be commodified for transmission; that is tacit knowledge, which is transmitted through workers. The amount of knowledge in either form varies depending on the characteristics of the individual, the complexity of knowledge, the usefulness, and other aspects. This also contributes to the value of the knowledge and its manifestations in products and workers. According to the resource-based view (Penrose, 1959), the bundling of these resources determines the capabilities of a firm, a sector, and a country.

Government policies and other institutions affect the accumulation of knowledge by influencing the creation, flows, and reduction. An intellectual property regime is necessary to enable the explicit knowledge in the form of patents to be traded in the market. These regimes define the length of time that patents last, which inherently reduce the value of knowledge if not knowledge itself. This affects the incentives that motivate actors to pursue knowledge activities. Government policies can also directly and indirectly support the creation and diffusion of knowledge, often by affecting the incentives involved. Support for investment in production or innovation capacity directly increases firms' motivations to adjust allocations towards these activities. Education policy also directs the type of workers and skills are supplied to the market. Direct R&D output can also be increased by introducing actors to the market, e.g. research institutes.

The elements used to analyze sectoral innovation systems are considered at the sector level but can also involve national-policies (Malerba, 2002; 2004). These elements are those institutions and policies that affect catching up in developing countries (Malerba and Mani, 2009; Malerba and Nelson, 2011; 2012; Malerba et al., 2017).

Affect how firms learn

Firms in developing countries develop learning capabilities similar to those in developed countries but less accumulated capabilities. Firms learn through production and innovation activity. Firms need to have the knowhow to engage in production activity and need to have the know-why to engage in R&D activities that produce innovation (Lall, 2000).

Production activity is often initiated through technology transfer through capital accumulation or foreign direct investment. R&D activities that lead to innovation can have more varied forms of impacts on innovation systems. Often the innovation capabilities are weak enough to be immeasurable through typical measures at the firm level, i.e. R&D expenditure. Sectoral innovation systems, however, sometimes provide aggregate levels of R&D activity that is measurable. Therefore, the impacts of spillovers depending on the form of knowledge channels can be differentiated (chapter 2).

Provide access to foreign knowhow

Actors in developing countries can often lack accumulated knowledge from domestic sources. Thus, access to foreign knowhow is an important factor for catch up. Direct knowledge flows can occur through embodied and disembodied knowledge that is in technological capital or in patents that are transmitted through market transactions. But sectoral spillovers also occur through embodied and disembodied knowledge spillovers (chapter 2), which should also be considered. Access to foreign knowhow can be gained through international trade, i.e. imported intermediate goods.

Improve skilled human capital

While tacit knowledge that improves the skills of human capital can be difficult to measure, the level of education is the typical measure for improved human capital skills. Vocation education can improve human capital for production. Higher education can also improve human capital so that knowledge workers are able to produce new knowledge. The know-why aspects are important to generate new knowledge that leads to innovation-driven growth and relies on different institutions to capture rents from that knowledge, i.e. IPR regimes.

Skills, however, can be locked into the technological regimes in which they are developed. Thus, allocation of human capital across different sectors should be considered in policies that target human capital development.

Active government policy

Although government policy can help develop the innovation system, the targets of the policies can determine the activeness and effectiveness of those policies. The policies are highly varied and often require coevolutionary abilities to ensure that the desired results are achieved.

3.4.2. Common aspects of industrial development of the auto sector in Korea and Thailand

The automobile industry moved towards globalization after the Second World War. Automakers from the United States were encouraged to expand their global production operations.[4] Similar to the European Recovery Plan of 1948, the United States promoted industrial development through aid to developing countries in the mid-1950s. South Korea and Thailand were both included in the process and developed similarly up until the late 1960s. Strong central government agencies were established to plan the development of the economies. In 1950, the National Economic and Social Development Board was established in Thailand. In 1961, the Economic Planning Board was established in Korea. These policies laid the foundation for promoting the industrialization of the economies.

The initialization of the auto industries were identical. Cars were imported before local production was introduced. In the 1960s, local firms were formed by partnering with US automakers that provided parts and knowhow. Domestic firms began to assemble completely knocked-down (CKD) car kits to sell to the local market. In the decade that followed, import substitution policies were encouraged to spur domestic development of technological capabilities, especially of core components.

Since they are exogenous to their economies, changes in global institutions also affected both countries equally. As globalization advanced, export markets became a target of potential economic growth. Developing countries were able to leverage lower cost of labor, if they could access technology. Export-oriented policies were introduced to both countries in the 1970s and 1980s. The advancement of international governing institutions, i.e.

[4] Trade barriers were common and the United States used economic ties to discourage foreign governments away from communism.

the WTO, meant that institutional norms were imposed through legal policies. Global economic shocks also affected both countries at the same time. The Asian Financial Crisis is a prominent example that was started in Thailand but spread throughout the world. It ultimately affected Korea and Thailand the most.

In the 1970s, however, the strategies used in Korea diverged from those in Thailand primarily through industrial organization and institutions for innovation. The development of technological capabilities can be seen in the ability of domestic firms to invent components for the automobile and eventually the entire automobile, in the case of Korea. The development of automotive components is considered a measure of technological capability in the sector. Moreover, the institutions that enable firms in the innovation system to achieve technological independence are an important aspect of analysis.

The early initialization period began by rapidly building production capabilities through technology transfer and FDI from foreign firms. Import substitution policies in both countries also provided protection from competition, thus increasing rents to domestic firms in the auto sector.

3.4.3. Comparison of capability development patterns of the auto sectors of Korea and Thailand

This section considers the divergence of the innovation systems as a process of the development of the industrialization of the auto sector. Although the beginnings of the auto industries in both countries are similar, the outcomes are stark. Hyundai is one of the top automakers in the world. Thailand may be the Detroit of Asia but it does not have a domestic carmaker. The innovation capabilities within the sectors of both countries are widely different as demonstrated by the network analysis in the previous section. Considering that analysis, knowledge networks are analyzed according to the type of knowledge flows. The sectoral innovation systems approach is applied to understand the possible causes of the lack of transition growth in Thailand.

Patents are a typical measure of innovation output. While the network analysis was performed on domestic patents, international patents are known to be more valuable. A search of the USPTO database returns over five-thousand patents issued to Hyundai Motor Company. A similar search for all Thai applicants returns just over seven-hundred.[5] As Gu (1999) points out, the innovation capabilities at the global level differs on the order of magnitude. This section explores the sectoral innovation systems of each country to find what accounts for the difference in transition.

R&D investments are one of the main factors of innovation capability development. Korea has strong innovation capabilities and invests in R&D activities (table 3-9). Thailand lacks innovation capabilities in the sector and invests a smaller amount in R&D (table 3-10). Yet, Korea may also be able to invest higher levels because its industry is larger. Private share of investment in R&D overtook public investment share in Korea in the 1980s. This reflects the higher returns that Korean auto companies get on their investment in R&D. In contrast, few companies in Thailand have been willing to invest in R&D, especially to develop new products. Efficiency-oriented process innovations

[5] Searches on 20 June 2019.

made Thai suppliers highly efficient but also left small margins that disincentivized innovations. Large automotive companies in Thailand rely on R&D capabilities from home markets because the local capacity is too limited.

Table 3-9: R&D inputs, Korea

	2009		2014	
	Value	Share	Value	Share
R&D Investment, motor vehicles (USD millions)	25.08	2.16%	32.82	1.16%
R&D Personnel, motor vehicles (FTE)	24,494	5.25%	31,977	5.28%

Source: OECD STI Indicators, share calculated by author

Table 3-10: R&D inputs, Thailand

	2009		2014	
	Value	Share	Value	Share
R&D investment, transport sector (million baht)	490	2.16%	739	1.16%
R&D personnel, transport sector (headcount)	975	0.88%	893	0.62%

Source: R&D Survey 2017, STI Office of Thailand.

After the initialization of the auto industry in Korea, the industry was tightly controlled. The government mandated that firms entering the automotive market have a “People’s Car” that was marketed domestically. Facilitated by partnerships with foreign carmakers, Hyundai developed the Pony model and Kia the Brisa using imported designs. Competition between producers was controlled by limiting producers licensed to operate and by segmenting the market between them. Although it accepted investment and technology from Mitsubishi in the early 1980s, Hyundai maintained control of the company.

While Korean brands suffered from reputations of poor quality abroad when Hyundai entered the US market in 1985, they were able to maintain small shares of the global market by targeting the subcompact market. Prior to entering the US market, Korean manufacturers exported a small number of cars to Latin America.

During this period, Korean car manufacturers were able to increase their local and technological content. By the late 1980s, local content of cars was over eighty percent. The consortiums of the 1970s and early 1980s led to increased technological capabilities. Moving towards internalizing its tacit knowledge production, Hyundai established several R&D centers in 1984. By the mid-1990s, Hyundai had become the top subcompact carmaker in the US and introduced its first wholly-designed mid-size model. Korean automakers were patenting core components of the automobile (tables 3-12–3-15).

The aftermath of the Asian Financial Crisis of 1997-1998 led to restructuring of the auto industry. Of the main Korean automakers, only Hyundai was able to survive. The typical forms of analysis suggest that it was able to acquire knowledge resources to achieve this. But what of the knowledge accumulated in the other carmakers? Kia Motors, Daewoo Motors, Samsung Motors, and Ssangyong were all bought out by other carmakers. While some observers at the time suggest that foreign automakers were uninterested in acquiring inferior patents (Ravenhill, 2001), the patents were usually transferred nonetheless. GM Korea (GMK) is listed as the rights holders for all the patents granted to applications by Daewoo Motors up to 2000.

Hyundai, the largest carmaker in Korea during this period, acquired Kia Motors, the second largest carmaker, which included Asia Motors that Kia acquired in 1978. Hyundai and Kia also had large majority of local content in their production. Yet, foreign carmakers were least interested in acquiring Hyundai's technology because it was less advanced than that of the foreign carmakers (Ravenhill, 2001). Hyundai managed to weather the Asian Financial Crisis and still creates its own technology in the sector including the new electric vehicle market.

When foreign carmakers acquired Korean car manufacturers, the function of knowledge creation from the firm slowed. Renault Motors acquired the assets of Samsung Motors. The chaebol business groups also enabled absorption of knowledge from firms that collapsed. Although GM acquired most patents in its buyout from Daewoo Motors, Daewoo Commercial Vehicle retain the last patents granted to its sister company from 2001.

Table 3-11: Patents granted to Korean automakers for combustion engine technology (IPC F02B), 1984-2016

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Asia Motor	0	0	1	1	0	0	4	0	0	0	0	0	0	0
Daewoo Motor	0	2	1	2	5	15	28	8	5	2	0	0	0	0
Hyundai Motor	4	6	32	19	64	71	181	82	7	44	36	40	47	56
Kia Motor	2	0	0	0	14	10	24	17	1	9	12	7	3	3
Samsung Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ssangyong Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Asia Motor	0	0	0	0	0	0	0	0	0	0	0	0	0
Daewoo Motor	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyundai Motor	29	31	56	63	51	42	24	45	45	72	41	44	47
Kia Motor	3	3	5	23	22	19	7	11	10	11	16	8	11
Samsung Motor	0	0	0	0	0	0	0	0	0	0	0	0	0
Ssangyong Motor	0	1	1	0	1	0	1	0	3	2	0	1	0

Source: KIPRIS Patent Database

Table 3-12: Patents granted to Korean conglomerates for combustion engine technology (IPC F02B), 1984-2016

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Daewoo	1	0	2	0	0	0	0	1	0	2	5	1	1	1	0	4
Hyundai	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	2
Samsung	0	0	0	1	0	0	0	1	0	0	0	2	1	1	0	0

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Daewoo	0	0	0	0	0	0	0	0	0	0	1	1	0	2	0	0
Hyundai	0	0	1	2	3	4	0	5	3	4	12	8	15	28	21	23
Samsung	0	0	0	0	0	0	2	0	1	1	13	13	5	4	3	1

Source: KIPRIS Patent Database

Table 3-13: Patents granted to Korean automakers for motor vehicle technology (IPC B62D), 1984-2016

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Asia Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Daewoo Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyundai Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kia Motor	4	3	8	21	10	11	12	66	379	178	97	1	61	147	112
Samsung Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ssangyong Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Asia Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Daewoo Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyundai Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kia Motor	68	79	118	48	73	84	63	45	52	66	63	38	28	42	46
Samsung Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ssangyong Motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: KIPRIS Patent Database

Table 3-14: Patents granted to Korean conglomerates for motor vehicle technology (IPC B62D), 1984-2016

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Daewoo	2	5	6	1	2	1	3	4	11	37	131	640	526	142	47	19	0
Hyundai	0	1	4	5	5	10	39	38	91	90	138	505	589	372	48	237	459
Samsung	0	0	0	2	7	4	4	7	8	7	5	7	14	4	0	3	0

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Daewoo	1	1	0	2	3	0	0	1	6	7	1	1	1	3	0	1
Hyundai	373	345	362	506	318	400	415	361	150	219	272	262	242	140	163	173
Samsung	0	1	1	3	3	3	3	12	2	20	10	8	1	2	0	0

Source: KIPRIS Patent Database

Table 3-15: Patents granted to Korean automakers, 1995-2005

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Hyundai Motors	4483	6946	3586	214	1995	2716	2573	2417	2514	2214	1443
Kia Motors	1872	1441	651	14	489	860	597	350	593	468	287
Daewoo Motors	4727	3912	1105	228	86	3	1*	2*	0	0	0
GMK (Daewoo)	n/a	n/a	n/a	n/a	2	6	8	15	11	15	36
Tata Daewoo	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	1	1	1
Samsung Motors	n/a	101	9	2	0	0	n/a	n/a	n/a	n/a	n/a
Renault Samsung	n/a	n/a	n/a	n/a	n/a	0	0	0	6	11	22
Ssangyong Motors	90	27	23	26	6	2	6	6	17	23	34

Source: KIPRIS Patent Database

Notes: * These patents rights list Daewoo Commercial Vehicle as patent rights holder. One of the inventors listed on the patents that transferred from Daewoo Motors to Daewoo Commercial Vehicle. He later invented patents for Tata Daewoo.

In the 1970s, the government of Thailand supported the development of the auto sector by extending the use of import substitution and local content requirement policies. These policies were similar to those adopted by Korea but they were not supplemented with R&D support for the industry. Instead, firms were encouraged to enter the supplier market, which was expected to increase efficiency through competition.

The current state of innovation capability in Thailand is undisputedly low in the automotive sector. At the USPTO, there have been only forty-eight patents granted to Thai inventors since 1976. Of these, only thirteen patents in the auto sector granted to Thai assignees. Seventeen of them have foreign companies as assignees.

The organizational structure of the auto industry in Thailand is dominated by foreign automakers. The top tier auto companies in Thailand are subsidiaries of foreign automakers, which are mostly Japanese. Toyota Thailand has a large majority of the production capacity (supply) and domestic market (demand) in Thailand.

In 1972, the government restricted foreign companies from operating without joint venture agreements with Thai subsidiaries. Similar to the chaebols in Korea, the companies at the top of the auto industry that mediate between foreign automakers and domestic suppliers were dominated by family-owned companies. The companies faced industry politics to gain market share including ties to banks that financed investments. The most successful of these firms became subsidiaries of foreign automakers. As subsidiaries, the top automotive companies produce some models that are suited for the domestic market but they are designed by parent companies.

There are no wholly-owned Thai companies of substantial size in the auto sector. Today, Thai Rung is the only automotive company that has a Thai-majority ownership. It was established as an assembler of Japanese automaker Isuzu in 1967. The company sells a national model but it still uses imported technology for assembly and is a supplier of vehicles to the military. The company has registered only three patents between 2009 and 2016.

Thai auto companies have an extremely low level of patenting (table 3-16). The Hyundai Motor company has registered more patents in for combustion engine technology (IPC code F02B) in some years than all firms in Thailand over a decade.

Table 3-16: Total granted patents by technology by year, Thailand all

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Total
Motor vehicle (B62D)	1	1	0	0	0	0	0	1	0	2	5
Engine (F02B)	1	0	0	0	0	0	1	1	0	1	4

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total
Motor vehicle (B62D)	2	1	0	2	3	11	7	5	2	7	40
Engine (F02B)	1	0	3	3	0	4	9	12	7	9	48

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Motor vehicle (B62D)	8	12	14	9	19	14	18	21	11	5	131
Engine (F02B)	8	19	11	16	4	15	19	17	15	3	127

	2011	2012	2013	2014	2015	2016	2017				Total
Motor vehicle (B62D)	21	33	50	43	28	9	10				194
Engine (F02B)	7	15	11	14	1	4	2				54

Source: Patent Database, Thai DIP, Ministry of Commerce

The Asian Financial Crisis started with the devaluation of the Thai baht. Similar to the effects in Korea, the industry was consolidated along the lower-tier suppliers. Another indirect effect was the loss of protection of local ownership, even in the upper tiers. Previously limited to minority ownership, foreign carmakers have opened greater production capacity spurred by demand policies. As foreign-owned companies expand their production capacity and market share, Thai Rung has lost considerable market share.

The non-industry actors in the innovation systems in Korea and Thailand operate quite differently. In Korea, research institutes and universities serve as innovators outside of firms that allowed accumulation of innovation capabilities prior to reaching critical mass necessary to compete globally. When tacit knowledge levels were sufficient to make economically feasible investments in R&D, Korean automakers were ready to accept the operational aspects of running R&D centers. In contrast, Thai suppliers in the auto industry do not tend to have in-house R&D units. The foreign carmakers have only recently begun to establish R&D units but they are usually used for testing, especially for local conditions. Thai university professors work primarily on small projects brought to them by local suppliers in the lower tiers. These projects tend to focus on meeting specifications provided by foreign MNCs through domestic subsidiaries.

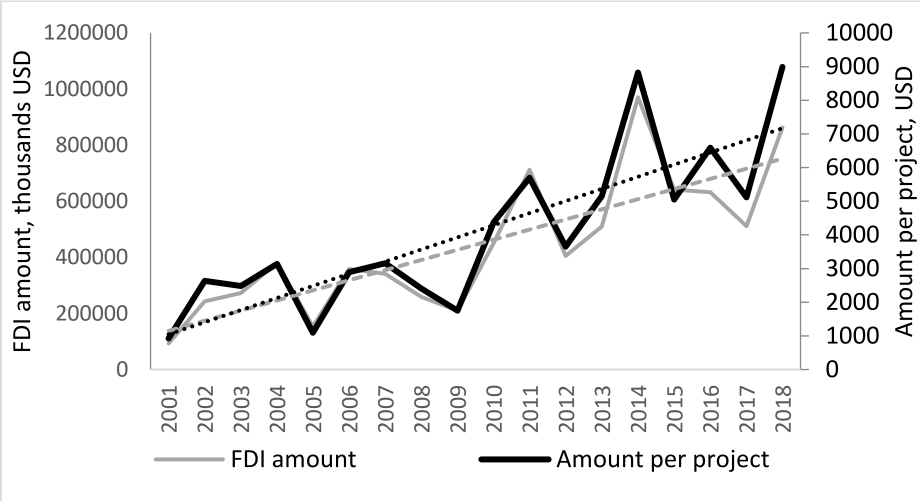
Furthermore, the organizational structure of the sector enabled local firms to recapture tacit knowledge that may be lost when firms exit the market. After the Asian Financial Crisis, Hyundai was able to absorb Kia's assets. While Hyundai Motors may have been vulnerable, nationalist sentiment encouraged domestic politicians and citizens to rally in support, despite opposition from wary labor unions (Ravenhill, 2001). Even though Hyundai Motors held patents that were of little value to foreign automakers, they represented accumulated tacit knowledge that enabled development of vehicles that meet future demand, e.g. electric vehicles.

The institutional policies that were used in Korea and Thailand were different in how they targeted different types of knowledge to support the development of the actors in the innovation systems. Initially, Korea restricted FDI and tightly controlled ownership and even management of auto companies. Today, there is more FDI allowed into the sector but joint ventures are still the main mode of entry for foreign carmakers. FDI in the broader machinery and equipment sector, which includes the auto sector, has increased overall and by project size (figure 16). FDI has been the main source of technological capability in Thailand. The level of FDI has been a much higher share of GDP than Korea. While the overall levels of FDI in the broader machinery and equipment sector continues to increase, the size of the projects have begun to shrink (figure 17). One of the effects of increased inward FDI flows is that imports and exports have increased along with it. Trade is expected to increase knowledge spillovers (Coe and Helpman, 1995).

The government was highly willing to intervene in both countries but the policies that were used were different. In Korea, the policies targeted production first but quickly included innovation capabilities. The general research capabilities of non-industry actors were developed ahead of firms. When clusters and consortiums were used to diffuse higher-level technological capabilities to industry, however, the firms were able to absorb the tacit knowledge such that they managed to develop their own research units in a short amount of time, then surpassing the amount of innovation produced in the sector.

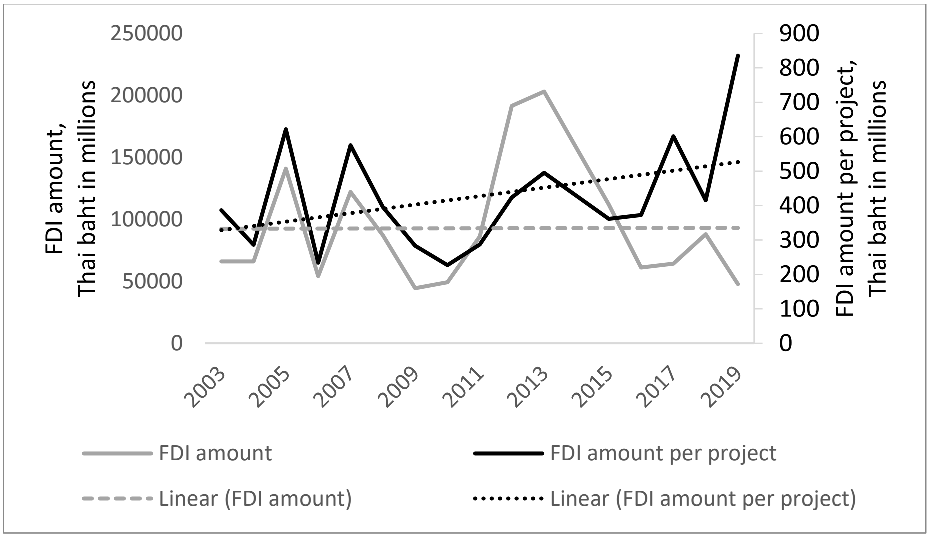
The government policies that were adopted in Thailand were similar in the mechanisms employed. Policies favored financial capital accumulation through FDI and business groups. Clusters were also formed to reduce transaction costs. The Thai Automotive Institute (TAI) was established in 1999 with the purpose of increasing technological capabilities in the industrial sector. Several master plans were adopted throughout the decades since 1977 (TAI, several years). Early industrialization efforts focused on technology transfer for production. The common factor among these policies, however, is that the technological capabilities almost always favored production capabilities over innovation capabilities. When innovation was targeted, it was through demand-oriented policies that required partnership with industry. Yet, none of these efforts resulted in innovation capabilities to be developed.

Figure 3-4: Total FDI and average FDI per project in Korea, the machinery and equipment sector



Source: Economic Statistics System, Bank of Korea

Figure 3-5: Total FDI and average FDI per project in Thailand, metal products and machinery



Source: FDI Investment Data, Board of Investment, Thailand

Note: Data for 2014 are missing but the lines are connected for visualization purposes.

In Korea, vocational education and training schools were established to develop skilled workers for industry and government research institutes to increase science and engineering capabilities in the 1960s. In the following decade, the government introduced policies that supported industrial development but also placed organizational burdens on them. The government introduced the Heavy and Chemical Industrialization and Plan for Nurturing the Auto Industry and Long-term Strategy for Promoting the Auto Industry in the early-half of the 1970s. These provided economic and R&D support to the automotive and other manufacturing sectors.

In Thailand, vocational education was implemented similarly to Korea. Yet, the results were not the same. Vocational graduates are a large part of the labor pool (table 3-17). The alignment of these vocational schools, however, do not meet industry needs, and they have not for many decades.

Another obvious difference is the level of education that has been provided. University education has only recently begun to increase the level of tertiary graduates (see next chapter section 4.4.2).

Table 3-17: Graduates in related areas of study by education level

Education Level	Korea 2018	Thailand 2015
Vocational certificate, engineering	6,272	61,643
Vocational diploma, engineering	3,018	53,945
Associate degree, engineering	40,772	n/a
Bachelor degree, engineering	81,919	39,838
Master degree, engineering	13,724	2,200
PhD degree, engineering	3,866	0

Source: Dataset on Tertiary Education, Korean Educational Statistical Service and Educational Statistics, Ministry of Education of Thailand.

Notes: The data are for the latest years available for the respective countries. Since the two countries title the fields of studies differently, the aggregations are matched as closely as possible. Korean data aggregates all engineering graduates together. Thai data aggregates engineering, manufacturing and construction fields of study together.

The organizational structure of the industry also discouraged investment in R&D because the risks posed were too large. The automotive industry is dominated by foreign-owned companies, especially MNCs (table 3-18). Domestic companies were incapable of jumping between the collective knowledge available to them and the innovations necessary to compete in domestic and foreign markets.

Table 3-18: Auto industry structure

	2005				2018*			
	No.	Thai	Most Thai	Most foreign	No.	Thai	JV	Most foreign
Assemblers	16	0%	100%	0%	17	0%	100%	0%
Tier 1 suppliers	648	23%	30%	47%	521	39%	3%	58%
Tier 2+ suppliers	1,641	100%	0%	0%	1,658	100%	0%	0%
Publicly-listed	19	n/a	n/a	n/a	19	n/a	n/a	n/a

Note: * Ownership restrictions were lifted, allowing full foreign ownership. "Thai" is purely Thai-owned, "Most Thai" is majority, "JV" is joint venture, and "Most Foreign" is majority foreign-owned.

Source: Thai Automotive Institute cited in Board of Investment (2007, 2018); and Stock Exchange of Thailand.

In 1979, the Thai Patent Act was passed enforcing legal protection of patents for the first time in the country. The Act was amended in 1992 and in 1999 expanding the scope and legal structures relevant to enforcement of intellectual property rights.

Without knowledge accumulation at the firm and sectoral levels, the costs of investing in R&D and the expected returns from innovation are too great.

3.5. Discussion

There have been many common policies that were implemented in Korea and Thailand at the initial stages of industrialization in the auto sector.

In the 1960s, centralized government agencies were provided with resources to improve industrialization, which quickly turned to the automotive sector. Early policies also adopted import substitution and later export-promotion. However, as time passed, the performance of the firms in the industry began to diverge because of the policies that differed. Hyundai was able to design its own electric vehicle in 2009, only a couple of years after the industry leader. Table 3-19 provides an overview of some of the policy interventions and milestones in both countries.

Table 3-19: Timeline of policy interventions and milestones in Korea and Thailand

Korea		Thailand	
Year	**Policy Intervention/Milestones**	**Year**	**Policy Intervention/Milestone**
1961	Economic Planning Board	1950	National Economic and Social Development Board, Office of Fiscal Policy of the Ministry of Finance; and Bureau of the Budget, Prime Minister's Office
1962	1st Five-Year Economic Development Plan (including auto industry)	1959	Board of Investment established
	1st car company: Saenara, later Daewoo-Nissan	1961	First National Economic and Social Development Plan
	Korean Auto Industries Cooperation Association established	1960s-1970s	Import substitution policies
1960s	Highway construction		
1966	Korea Institute of Science & Technology established		
1967-1974	Three other companies enter: Hyuandai-Ford, Asia Motors-Fiat, and Kia-Mazda (began with motorcycles)		
1970s	Technology transfer agreements	1970s	Association of Thai Industries
		1972	Alien Business Act
1973	Declaration of Heavy and Chemical Industrialization and Plan for Nurturing the Auto Industry		
1974	Long-term Strategy for Promoting		

	the Auto Industry		
1975	1st Korean auto model (Hyundai Pony)		
		1977	Investment Promotion Act and 1st Thailand Automotive Industry Master Plan
1978	Policy allowing subcontracting of components to promote parts sector Local R&D lab established (Hyundai)	1978	Thai Automotive Parts Manufacturers' Association
		1979	Thai Patent Act
1980s	Content requirements	1980s	Export promotion policies
	Preferential taxes	1983	Industrial Restructuring Committee
1982	Automobile Industry Rationalization Plan		
1984	Additional R&D centers established abroad (Hyundai)	1984	Devaluation of currency
1986	Hyundai enters US market (subcompact) American Technical Center		
		1987	ASEAN Industrial Cooperation Scheme (part of ASEAN Free Trade)
1988	Automobile Manufacturers Association		
1990	Million cars produced	1990	First autonomous university (Suranee University of Technology)
1991	Locally designed engine Abandon import production	1992	Thai Patent Act amended
1994	First locally designed subcompact		
1990s	Top 10 car manufacturer	1997	Currency devaluation; Asian Financial Crisis
1997	Asian Financial Crisis	1998	Thailand Automotive Institute
		1999	Foreign Business Act amended to allow foreign ownership
2000	Joined California Fuel Cell Partnership	2005	Million cars produced
		2006	Thai-Nichi Institute established
		2007	Thailand Automotive Industry Master Plan 2007-2012
			Foreign Business Act amended to allow support to foreign owned companies
2009	First all-electric vehicle prototype (Hyundai)		

This findings of this chapter are twofold. First, network analysis was performed to quantitatively demonstrate the sectoral innovation system transition in Korea and the transition failure in Thailand. The network analysis also showed the differences within the countries' innovation systems, demonstrating that change in the industrial sector knowledge flows stems from innovation capabilities in Korea and production capabilities in Thailand. Second, a comparative analysis of the sectoral innovation systems in Korea and Thailand demonstrate the dynamics underlying the change in the innovation systems.

The statistical analysis of the increase in knowledge flow networks in each country provides empirical evidence regarding the differences between the two countries. The difference between the countries confirms that Korea increased its knowledge networks significantly compared to Thailand. More importantly, Korea improved its knowledge flows across its industrial sectors for both channels of knowledge and different relativization measures. Thailand has been able to increase the disembodied aspects of its knowledge networks but not its embodied knowledge flows. Moreover, the inflows of knowledge from other industrial sectors is stronger in Korea than in Thailand, especially for disembodied knowledge channels. The outflows have less impact on other industrial sectors but that may be expected since transportation technology is difficult to apply as general purpose technology.

An auto industry sectoral innovation system should have institutions that develop innovation-based capabilities in general. Domestic ownership at the sector level is important for driving country-sector innovation capabilities.

A national branded car company was part of how innovation capabilities were developed domestically in Korea. Moreover, the companies that were reliant on foreign partnership were driven out of the market. There are several reasons that are identified for why these institutions fail to develop innovation capabilities in Thailand but the main reason is that incentives have been misaligned. The dominance of foreign MNCs shifted industrial policy towards production capabilities rather than innovation capabilities. Domestic firms were at a comparative disadvantage without policy support to counterbalance technological capability development. The electronics sector faced similar difficulties.

Government policies should develop knowledge accumulation targeting more difficult and thus more valuable knowledge. Through consortiums and research institutes, the Korean government support allowed non-market feasible R&D to persist, enabling pre-commercial R&D activities to continue. In contrast, the Thai government relied on market forces to encourage technological capability development. This alignment, however, favored firms that already had technological capabilities, namely the MNCs. Domestic suppliers were only able to chase after production capabilities that were efficiency-oriented.

In general, the learning capabilities that were developed in Korea enabled the creation of new designs, incrementally at first and then approaching radical innovation. Although Hyundai did not create radical innovations in the automotive sector, its innovation capabilities allowed it to move to new technologies soon after those firms at the frontier. Without innovation capabilities, sectors are constrained to mature technological paradigms. The technological capability building institutions in Thailand incentivize production efficiency over innovative technological change. The inherent problem is that efficiency leads to technological change that has decreasing rates of return, whereas innovative technological change has increasing rates of return.

Furthermore, manufacturing sectors have different characteristics that lead to different problems. The sectors in Thailand that export goods tend to be dominated by foreign MNCs. Protected sectors tend to be dominated by monopolies or oligarchies. The reasons for the lack of innovation capabilities development can vary depending on the characteristics related to the industrial sector.

Chapter 4.

Capability development patterns in the national innovation system in Korea and Thailand

4.1. Introduction

The World Bank (2013) found that Korea was one of the few middle-income countries that escaped to high-income. Moreover, it is known to have done so by industrializing and developing its technological capabilities. Today, Korea is one of the top patenting countries in the world, following Japan, the United States, Germany, the United Kingdom, and France. While Thailand has managed to grow at significantly high rates in the 1980s, it has failed to reach those high levels of growth again. Its innovation capabilities are miniscule in comparison. This study follows in the tradition of other studies of national innovation systems in developing countries, especially a wide body of work that has been completed by Patarapong Intarakumnerd on Thailand (Intarakumnerd and Chaminade, 2007; Intarakumnerd et al., 2002; 2011) and others on national innovation systems in development (Lundvall et al., 2002; 2009; Siyanbola et al., 2012).

The study of economics has a long history of nation-level analysis of economic performance that goes back to at least the early 19th century. Ricardian comparative advantage considers aggregate economic welfare between countries. The concept of a "national system of political economy" originated with List (1841/1909, pp. xvii-xviii), focusing on nationality "as the distinguishing characteristic of [his] system." The emergence of the national innovation system concept grew out of this branch of study by focusing on the aspects of economic and knowledge dynamics (Freeman, 1987; Lundvall, 1988; 1992; Nelson, 1992). Gu (1999) extended the NIS analysis to transition of developing countries by focusing on initializing innovation capabilities that do not exist, as opposed to those in advanced countries that are supposed to have innovation capabilities by definition. The need for developing countries to transition to innovation-driven strategies is the main concern of national innovation systems literature; yet how lower-middle income countries manage the transition is still not well understood, evidenced by the lack of transition in most middle-income countries.

This chapter will be a comparative case study of the middle-income trap and national innovation systems in Korea and Thailand to determine why Korea escaped the middle-income trap and why Thailand did not. The main argument of the chapter is that the middle-income trap is the result of transition failure of a national innovation system; a national innovation system must transition towards innovation to avoid the middle-income trap. As I argue that the innovation system transition failure ultimately results in failure to sustain economic growth, this chapter focuses on transition or transition failure as it relates to the innovation system, rather than to economic growth. By contrasting innovation failure from economic failure, this study differentiates itself from previous studies that focus on catching up, which does distinguish the specific sources of growth in its analysis. Despite recognizing the differences in the capabilities that drive economic growth, focusing on catching up limited those studies by failing to recognize that catch-up under certain determinants of growth are not the same as others. Specifically, strong production capability does not guarantee the development of innovation capability for transition.

Structural change is one of the foundations of economic development. The Lewis-Kuznets framework captures the shift from lower-income countries to middle-income countries by shifting from extraction of agricultural and mineral goods to more productive manufacturing sectors (Vivarelli, 2014; Agenor, 2016). When economies shift labor resources to more productive segments of the economy, growth is the expected outcome. The countries that fail to achieve this shift from low-income are trapped in poverty due to fundamental conditions, e.g. conflicts and bad governance.[6] Once those initial conditions are met to overcome poverty traps, however, the causes of the middle-income trap change focus to structural differences between middle- and high-income economies. The difference in economic and industrial structures alter the sources of economic growth.

Previous studies held that increased levels of resources, through population growth or investment for instance, would lead to economic growth. Early conclusions suggested that savings rates were a primary source of growth. Technological change, however, promotes economic growth while holding resource inputs constant, treating technological change exogenously (Solow, 1956; 1962). In the developing context, the available knowledge base needed for innovation is further from the technological frontier than in advanced countries, but labor costs are lower. Latecomer countries, according to this

[6] Collier (2007) provides a discussion on this phenomenon and its causes in *The Bottom Billion*.

approach, should thus have an advantage of “backwardness” because they can adopt new technologies without the costs associated with creating them, enabling production with cheaper capital and labor costs (Gerschenkron, 1967; Mathews, 2002). This model inspired the Flying Geese model of development (Akamatsu, 1961), which is no longer fashionable because it has not proven a successful means of catch-up.

Growth can be driven through structural change or through productivity growth. Diao et al. (2017) develop a model of structural dualism between the traditional agricultural sector and manufacturing. They look at the growth in developing parts of the world outside of East Asia, i.e. Latin America and Africa, and find that different patterns of structural change and economic growth take place. By decomposing labor movement and productivity, Diao et al. (2017) are able to compare the relative within and between sector productivity. This difference results in different drivers of economic growth through structural change and through productivity. For instance, the policies and resulting incentives differ between the dual markets yet how these policies impacts the markets through technological change are not well described in current studies.

Although technological change or innovation is defined as the main driver of economic growth, how innovation occurs in developing countries is still not well understood. There are some theoretical studies that have included innovation components in later stage development that enables middle-income countries to become advanced ones (Vivarelli, 2014; Radosevic and Yoruk, 2016). Vivarelli (2014) examines absorptive capacity, as specified by innovation literature, and entrepreneurial capabilities, from management studies, can be combined to better understand development research. Also drawing from innovation studies, Radosevic and Yoruk (2016) advise that a framework of technological capabilities across specialty, intensity, and global source is necessary for middle-income countries to advance and call for new relevant indicators to be created. Factors that enable middle-income countries to overcome the failure to transition to high income still focus on factor markets, i.e. factor productivity; institutional differences, i.e. intellectual property rights protection, macroeconomic policy, trade openness, democratic principles, inequality, and financial reform; and a few endogenous factors, i.e. education and innovation activities (Agenor, 2016).

In summary, countries have managed to promote economic growth through structural change to achieve higher levels of productivity. Technology transfer is the main conduit for accessing technologies in developing countries but institutions governing the transfer changed, making it more difficult and costly to access the technologies again. This occurred as institutions governing intellectual property changed, limiting international technology transfer, i.e. through multilateral agreements such as the WTO TRIPS. These approaches, however, failed to address innovation during transition. Without comparative advantages of lower labor costs, middle-income countries need an indigenous source of technology.

The following section will provide a literature review of the middle-income trap, national innovation systems, and transition failure. Section 4.3 will compare the patterns of capability development of actors in Korea and Thailand using the national innovation systems approach. Section 4.4 then examines the institutions and policies that affect the development patterns. The chapter closes with a discussion of the findings and implications for middle-income countries that may face the middle-income trap.

4.2. Middle income trap, national innovation systems, and transition failure

4.2.1. The middle-income trap

Although the World Bank introduced the subject of the "middle-income trap" as a focus of study in 2006 (Gill and Kharas, 2007), the research concern of economic growth related to income-level reaches back further. In a certain respect, contemporary fears regarding the middle-income trap evolved from studies on convergence (Barro et al., 1991; Baumol, 1986; Quah, 1996), and later divergence (Pritchett, 1997; Quah, 1996). In both cases, income-levels were correlated with different rates of growth, but whether this growth was positive or negative changed over time. Institutional variables related to income were thus sought to explain the disparities (Beckert, 2010). Several studies wade into the debate whether middle-income countries are more likely to grow slower than countries at different income levels (Eichengreen et al., 2013; Aiyar, 2013; Pritchett and Summers, 2014; Im and Rosenblatt, 2015). Rather than consider the debate over whether there is or there is not a middle-income trap, this dissertation examines the transition of sources of growth in middle-income.

There have been many studies on the middle-income trap since the term was first introduced just over a decade ago. They can be divided between crosscountry studies and country case studies. Early examinations of middle-income countries raised institutional and industrial factors as possible causes of slowdown (Foxley et al., 2011). The alternate strand of empirical studies spanned across countries to determine what the causes of slowdown might be (table 4-1). Eichengreen et al. (2014) finds that manufacturing is positively correlated with growth, especially with technology-related exports. Currency undervaluation, inflation, and the dependence on low-skilled labor are the main deterrents to reaching high-income. Aiyar et al. (2013) finds a higher frequency of slowdowns in middle-income countries and considers a broad range of explanatory variables, which are grouped into categories to overcome data limitations. The categories are institutions, demography, infrastructure, the macroeconomic environment, economic structure and trade structure. Yilmaz (2016) finds that labor productivity differences are a main source of the middle-income trap especially as the economy shifts towards manufacturing. Similar studies examine trade statistics to determine factors of growth (or slowdown) in exports. Felipe et al. (2014) look at the trade statistics of the countries and found that exports were more diversified, sophisticated, and non-standard in those countries that advance between income levels.

Han and Wei (2015) identify determinants for growth based on countries at similar income levels. First, they identify whether or not countries are caught in low-income or middle-income traps based on probabilities of countries escaping their income band in the past and then determine what causes a country to remain in an income group or escape. The growth determinants considered are political stability, macroeconomic stability, investment infrastructure, investment in human capital, trade and investment openness, governance, inequality, initial income, demography, the global economic environment, and oil export indicator. The results show that the causes of economic growth change as the level of income changes or as countries transition in and out of middle-income.

Despite the varied methods for determining whether or not a country is in the middle-income trap (or what countries qualify as middle-income), the proposed causes tend to be consistent but broad: democratic institutions, culture, infrastructure, trade openness, technological sophistication, and economic structure. Several studies determine that there are different factors affecting the growth in different middle-income countries with various impacts (Lee, 2013; Bien et al., 2016; Zhang, 2016). The central dynamic is the failure to transition the economy to high-value products and services after capital-driven production is initially adopted. The common conclusion is that innovation-driven growth is necessary to function as an advanced country and economies that fall into the middle-income trap have failed to develop the necessary innovation inputs and infrastructure. The possible number of causes poses complications of tractability of the proposed factors.

Table 4-1: Empirical research on the middle-income trap

Study	Key Findings	Explanatory Variables
Aiyar et al., 2013	Middle-income trap exists; use 7 groups of categories of explanatory variables	Institutions, demography, infrastructure, the macroeconomic environment, output structure and trade structure

Bulman et al. (2014)	Higher rates of TFP growth, low inflation, and fast transformation	Export-orientation, industrialization, low inequality
Doner and Schneider (2019)	Examines political economy for institutional weaknesses	Education quality, R&D investment
Eichengreen et al., 2011	Uses Hausmann et al, 2005 model to describe slowdowns of middle-income countries; slowdowns occur more often when countries reach GDP per capita of $11,000	GDP per capita, growth, demographics, manufacturing, exchange rate (undervalued), and inflation
Eichengreen et al., 2014	Revisits 2011 study but finds a second point of slowdown at GDP per capita of $16,000; additional factors are considered	+human capital (high-skilled labor)
Felipe et al., 2013	Defines statistical aspects of the middle-income trap such as periods and rates of growth	More diversified, sophisticated, and non-standard trade products
Han and Wei, 2015	Different causes for slowdown exist for countries at different income levels	Low-income countries: population, infrastructure, FDI, income, natural resources, schooling, inflation, government debt, etc. Middle-income countries: population, crises, income, FDI, competitiveness, inflation, etc.
Im and Rosenblatt, 2015	Using transition matrices, find that likelihood of transitioning to higher	n/a

	income levels is no more likely in middle-income than low- and high-income	
Ye and Robertson, 2016	Find only 7 countries in middle-income trap defined by unit root test	n/a
Yilmaz, 2016	Using shift-share analysis to decompose labor productivity into static and dynamic structural shifts in sectors	Manufacturing main driver
Zhang, 2014	Finds that countries at different levels of growth have different causes of growth	Low income: Fixed capital, FDI and human capital accumulation Middle-income: institutions and R&D

Studies on specific countries tend to be focused on mostly on China and Southeast Asian countries (table 4-2). Several studies on China focus on the political economy and identify political institutions as the possible escapes from a potential middle-income trap (Liu et al., 2017; Wang, 2016; Woo, 2009; Yao, 2015). China, however, has only been in middle-income for about a decade and is still growing quickly so lumping it in the rest may be premature.

Ohno (2009) compares Vietnam to other Asian countries to determine factors that might help Vietnam avoid the middle-income growth trap the way Korea and Taiwan did and how Thailand and Malaysia may not have, based on the stages of industrialization. Vietnam has grown rapidly by expanding its physical capital base but remains at a lower stage of industrialization. Ohno (2009) determines that catching up industries must improve their productivity by focusing on labor and manufacturing productivities through education, productivity enhancement, sector targeting, and market orientation. Since the growth transition was triggered through centralized policies in Vietnam, Hoai et al. (2016) examine it and its experience of structural transformation as its income grows and slows. They find that low-cost labor advantages of productivity are already being lost (at GDP per capita of only $1,910 in 2013) and improved productivity through innovation and human resource development is necessary for further growth. Several other causes that are identified for the middle-income trap stem from structural changes that occur as economies grow from low to middle to high income. These include diminishing returns to capital, exhaustion of cheap labor and technology, lack of high skilled labor, distorted incentive schemes, and lack of or inappropriate infrastructure (Agenor, 2016).

Malaysia and Thailand have been the focus of many middle-income studies because they were at the heart of the initial discussion; two of the second group of Asian Tigers that managed to industrialize. Hill et al. (2012) examine Malaysia and determine that its slowdown is the result of poor governance that limits its economic transition. While its growth and transition were rapid, it was highly volatile and constrained by policies that left it dependent on low-skill labor. Malaysia and Thailand have similar problems in developing human capital skills (Jimenez et al., 2012). Many studies have focused on many aspects of the weak national innovation system in Thailand and find that many of the typical sources of technological capability building have been ineffective (Intarakumnerd, 2011; Intarakumnerd et al., 2007; 2012).

Generally, assuming macroeconomic conditions are good, the middle-income trap suffers from a productivity slowdown as a result of a failure to build technological capabilities, which depends on human capital development.

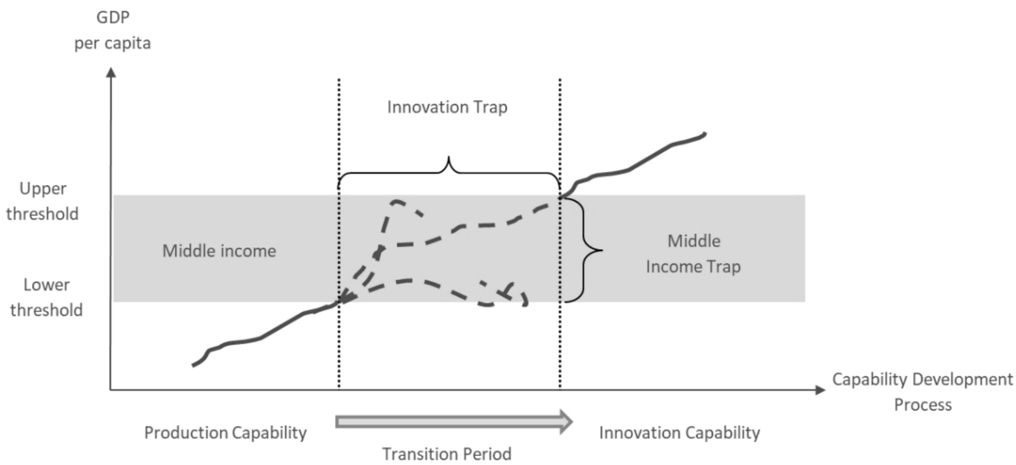
Table 4-2: Country case studies on the middle-income trap

Study	Key Findings	Country
Cherif and Hasanov (2015)	Domestic technological capabilities	Malaysia
Dabus et al (2016)	Bad equilibrium of infrastructure, human capital development, and investment	Argentina
Hill et al. (2012)	Poor governance leads to MIT	Malaysia
Intarakumnerd and Chaminade (2007)	Poor implementation of policy	Thailand
Intarakumnerd et al. (2002)	Weak linkages in NIS	Thailand
Intarakumnerd (2011)	Transferring capabilities to firms is difficult	Thailand
Jimenez et al. (2012)	Quality of education	Malaysia, Thailand
Jitsuchon (2012)	Coevolution of institutions	Thailand
Klingler-Vidra and Wade (2019)	Poor investment choices, low financial capacity	Vietnam
Liu et al. (2017)	Innovation policy necessary	China
Ohno (2011)	Manufacturing productivity slows	Vietnam
Wang (2016)	Vested interests prevent innovation	China
Woo (2009)	Policies overemphasize redistribution of income	Malaysia
Woo (2012)	Poor governance leads to MIT	China
Yao (2015)	Instability causes MIT	China

Yusef and Nabeshima (2009)	Localization of technologies	Malaysia

The middle-income trap may be caused by the failure to transform an economy to a higher level of productivity (Lee et al., 2019). The process of transition ultimately depends on technological capabilities to introduce new innovations and on the ability to diffuse those innovation through implementation capabilities for the new innovations. Figure 4-1 illustrates how countries end up in the middle-income trap as a result of an innovation trap; only countries that are able to develop innovation capabilities transition to high-income levels.

Figure 4-1: Innovation-oriented Middle-Income Growth Trap



Source: Adapted from Lee et al. (2019)

4.2.1. National innovation system and catch-up

Innovation systems provide a framework of how innovation is created with knowledge and technology by actors and transmitted across networks (Edquist, 1997; Lundvall, 1992; Nelson, 1992). While they are often circumscribed with technological (Carlsson and Stankiewicz, 1991), regional (Cooke et al., 1997), sectoral (Malerba, 2002; 2004), national (Lundvall, 1992; Nelson, 1992), and global (Binz and Truffer, 2017) boundaries, innovation systems define characteristics (Edquist, 1997) of the knowledge and technologies, innovation actors and their networks, demand, and the institutions that govern their interactions. Institutions and policies that drive innovation, however, are often defined by national policies.

While firms are the primary actors that introduce innovations to the market, they do so in conjunction with other actors that promote flows of knowledge along networks in the innovation system. Interactions of firms through user-producer relationships leads to accumulation of knowledge (Lundvall, 1988). The role of universities and research institutes are also to create and diffuse tacit knowledge within an innovation system and also sometimes provide R&D activity and outputs through interactions with industry (Nelson, 1992; Lundall; 1992). Linkages through other means such as associations and government consortiums can also encourage tacit knowledge flows. Associations can facilitate the flow of knowledge and even workers within the system as well (Watkins et al., 2015).

Previous studies on the national innovation system have focused on how and why some countries have managed to catch-up successfully while others have not. One of the early researchers in national innovation systems, Lundvall, has approached the aspect of developing countries through a several compilations of studies (Lundvall, 2007; Lundvall et al., 2002; 2009). Lundvall et al. (2009) present a series of studies that address development economic concerns. Cirera and Maloney (2017) identify the failure of firms to develop advanced technological capabilities of invention as a result of missing complementarities and poor government capabilities to identify the missing complementarities. This framework relies on the idea that firms rely on competitive advantage in order to succeed (Porter, 1990) and require dynamic capabilities to ensure that they capitalize on their core capabilities (Teece and Pisano, 1997; Teece, 2009). Failure to catch up is thus rooted in the resource-based view that suggests a firm's performance is based on its ability to accumulate and mobilize resources in competition with other firms in the market (Penrose, 1959).

As technological change became understood to underpin economic growth (Solow, 1956), the study of innovation systems emerged to better understand the characteristics that drives innovation in economies. Knowledge was also linked to technological change as the driving input (Bell, 1973). Economic development occurs through accumulation of technological capabilities that are not always linear (Nelson and Winter, 1982). Related new growth theory suggests that knowledge can be proxied by skilled human resources and patents (Grilliches, 1991; Romer, 1986; 1990). This stresses the importance of a skilled workforce. Knowledge workers provide the tacit knowledge that drives innovation by improving functional, production and innovation capabilities (Lin and Chen, 2006).

Accumulating knowledge is the basis to catch-up through structural transition. Nelson and Winter (1982) highlight the need for organizational memory in the seminal work on evolutionary economics. Even at the national level, knowledge bases are developed through the capabilities of firms developed through absorptive learning (Stiglitz, 1987; Cohen and Levinthal, 1989; 1990) and dynamic capabilities (Teece, 1997). Knowledge creation is achieved through recombination (Eisenhardt and Martin, 2000). Developed and developing countries accumulate technical and technological capabilities at differing rates (Bell and Pavitt, 1993).

The government role can vary in an innovation system but as the source of laws and policies, it can drive innovation in an economy or even suppress it. Many institutions and policies affect how financial resources are allocated in an innovation system. Financial markets can facilitate the innovation capability building within a national innovation system. Intellectual property rights regimes also affect how incentives affect investments in R&D. Therefore, government policies should be strategic in developing innovation capabilities.

Catch-up, however, does not equate to transition, which requires innovation. Thus, the prospect of transition failure still remains. The characteristics of tacit knowledge related to accumulation challenge existing theoretical constructs on innovation systems and are highlighted in the next section, focusing on transition.

4.2.2. Innovation system transition failure

Development through structural change occurs by industrializing in stages from imitation of production capabilities to innovation (Kim, 1997; Lall, 1992). Structural change is enabled by introducing technology to an economy that leads to a higher level of productivity than previously existed. To initialize the structural change or industrialization process, economies transfer technologies from abroad and grow more rapidly (Radosevic, 1999). Labor shifts from lower productivity sectors, e.g. agriculture, towards ones with higher productivity, e.g. manufacturing (Lewis, 1952; Kuznets, 1955). But without the introduction of new technology, markets will reach equilibrium at lower levels of development, based on the Cobb-Douglass share of substitution between capital and labor. For developing countries, the need to transition to innovation-driven growth is acknowledged but not well understood.

How latecomer countries end up transitioning from production to innovation capabilities is only partially described through catch-up. Acemoglu et al. (2006) find that early stage developing countries use more investment-driven strategies and those closer to the technological frontier switch to innovation-driven strategies. MacMillan and Rodrik (2013) find that differences of economic growth within and between sectors of structural change can determine whether economic growth is achieved or not. The transition from middle income to high income requires development of institutions that does not occur automatically. Several causes for the middle-income trap have been identified that catch these economies in “bad equilibriums” as a result of institutional frameworks (Agenor, 2016). The determinants are similar to those found in an innovation system, e.g. poor infrastructure, insufficient knowledge workers and finance capital.

In a complex environment, system failures can arise through infrastructure failure, network failure, lock-in failure, and/or institutional failure (Smith, 2000; Woolthius et al., 2005; Metcalfe, 2005; Weber and Rohracher, 2012). Lack of general infrastructure or macroeconomic institutions can lead to system failures, especially in lower-income countries that are in poverty traps, but these are differentiated from middle-income traps, which point to a lack of increased productivity of capital and human capital (Agenor, 2017). Infrastructure failure occurs when necessary infrastructure outside of the firm but necessary for an industry is not provided within the economy. Network failure is when necessary actors within the system are not available or unable to interact with each other. Lock-in failure exists when firms have invested in existing technological trajectories and paradigms, failing to adopt new technologies necessary for imminent industries. Institutional failure can arise when institutions too strongly reinforce existing industry behaviors. Alternatively, institutions necessary for new industries can be absent or too weak. The effects of knowledge embodied in skilled human capital requires a critical mass (Azariadis and Drazen, 1990), which can be interpreted as another potential source of failure.

In addition to these market and structural failures within a system, Rodrik (1996) finds that coordination failure can occur when governments are unable to establish institutions that lead to the more favorable of multiple equilibriums across the economy. Weber and Rohracher (2012) add broad aspects in which the entire system fails to transform itself by failing to provide direction, articulate demand, or enable actors to self-organize. At the global level, Spence (2011) highlights an "adding-up problem" where several countries target the same sector(s), leading to an oversupply.

The possibility of transition failure suggests the need for an appropriate innovation strategy during the transition period. Moreover, the diversity of institutions that affect the development of systems requires a complementary arrangement be made for successful development through innovation and learning (Amable, 2000). While there are many aspects of the innovation system that can be affected exogenously, the aspects that have direct impacts on technological change in industry are those that affect innovation. Escape from possible middle-income traps requires that developing countries acquire transition capabilities to move from production-driven growth to innovation-driven growth (Gu, 1999; Lee et al., 2019). The underlying determinant is (insufficient) knowledge accumulation.

One of the main conclusions derived from structural change research is that firms in developing countries must diversify the industries of the economy. Diversification follows a u-shaped pattern according to development, suggesting middle-income countries should specialize industries as they increase in income (Imbs and Wacziarg, 2003). As developing countries develop, the complexity of the economic structures also increases as countries advance. Thus, developing countries should adopt policies that build capabilities according to the level of development (Lee and Mathews, 2010). Hobday (2003) finds that developing countries can take a Gerschenkronian perspective, developing along industrial segments of technology, e.g. OEM and OBM stages.[7] This stage strategy to innovation points to the need of a critical mass of knowledge needed to succeed in an industry. The corollary is that if nation-sectors can succeed, then they can also fail.

Considering the approaches of structural change generally, technological capabilities for production output is the main focus of economic growth in development. Latecomers, however, face barriers to transition when they fail to develop innovation capabilities (Choung et al., 2000). Yet, production-innovation dichotomy can still lead to the transition trap. One study finds that general production growth is the typical measure for success in an industry but may not necessarily equate with innovation capacity growth (Bleda and del Rio, 2013).

Since structural change is one of the main mechanisms for economic growth, the relationship between learning capabilities and efficiency-driven productivity efficiency and innovation-driven growth are examined.

4.3. Capabilities development patterns in actors of Korea and Thailand

Past studies on the development of national innovation systems identify different elements of national innovation systems that are necessary to change accumulation of capabilities (Bartels et al., 2012; Intarakumnerd and

[7] An OEM is an original equipment manufacturer and an OBM is an original brand manufacturer. The differences refer to the ownership of technology that is used in the manufacturing process.

Chaminade, 2007; Intarakumnerd and Virasa, 2004; Nelson, 2008). Nelson (2008) argues for the need for evolutionary innovation systems theory in development because modern economics requires the ability to analyze economic dynamics and evolutionary theory is already affecting neoclassical economic research. For instance, it may not be possible to "maximize" an economy where the institutional terms of maximization change. Intarakumnerd and Chaminade (2007) suggest transformation of weak NISs in developing countries by focusing on strategic innovation system instruments without relying on neoclassical concepts of optimality, equilibrium, and failure. The instruments are divided between neoclassical, e.g. R&D subsidies, R&D tax breaks, establishing R&D institutes, promotion of S&T manpower, and innovation systems approaches, e.g. training of firms, network strengthening, facilitating access to foreign sources of knowledge, supporting business services, and improving user-producer interaction. Intarakumnerd and Virasa (2004) provide a taxonomy of a firm's development of technology capabilities as they relate to strategies and external linkages and the policies that support them. Metcalfe and Georghiou (1997) divide the types of growth and the necessary institutions that drive them. This paper refers to these two types of growth as efficiency-productivity and innovation-driven growth.

Efficiency-driven productivity growth

Production capabilities are shown to initialize the industrialization process in developing countries (Lall, 1992). Production capabilities require a lower level of tacit knowledge input and use production capital that has knowledge embedded in its design. Technology transfer from outside the innovation system is possible through FDI (Radosevic, 1999). Thus, locating production activity in economies with lower labor costs, i.e. developing countries, is a matter of investment capabilities. Institutional and policy strategies involve ensuring necessary trade policies and reallocation of financial resources through domestic credit policy or FDI attraction (Lall, 2001).

Infrastructure development and institutional policies can also support efficiency strategies by lower costs of transactions for domestic firms or costs of localization by foreign firms. Cluster-based development policies are an example of how this happens, especially through special economic zones (Ketels and Memedovic, 2008).

Innovation driven growth

Business is based on the transactions of goods, placing firms as the focus of the innovation process. The process, however, requires knowledge inputs that adds value to physical resources embodied in business products sold. Moreover, the value associated with innovation capabilities are varied depending on the type of knowledge (Grant, 1991). One of the inherent differences between production and innovation capabilities (as opposed to invention capabilities) is that innovation capabilities are deemed more valuable because they are more difficult to transfer and/or replicate. Another difference of knowledge types are the modes of innovation required to create them. Innovations derived from learning-by-doing/using/interacting tend to be non-technological while those created through science and technology-based innovation tend to be technological (Parrilli and Heras, 2016). Thus, education policies are part of innovation strategies.

There are many other innovation strategies that can be found. Strategies that focus on supply and demand of innovation inputs and outputs are common. The supply of knowledge workers, R&D funding, and patents is expected to lead to output of high value production and economic growth. The structure of these inputs may also affect economic performance. For instance, previous studies consider technology-supply targeting policies focusing on horizontal and vertical priorities (Lall and Teubal, 1998). Policy instruments also target demand conditions related to innovation, e.g. export promotion. Peters et al. (2012) suggest a need to consider supranational demand-pull policy schemes. Since equilibrium prices are higher in wealthier countries, developing countries can readily target them with export promotion policies.

Within the developing context, technological catch up occurs in different patterns than in developed countries (Lee and Malerba, 2017). The strategies used to accomplish catch-up are different than those adopted by firms in advanced countries (Mathews, 2002). Rapid absorption of implementation through imitation and technology transfer can account for catch-up when technology is affordable. If firms in developing countries can finance the costs of technology transfer, then it is possible for the firms in developing countries to conduct production activity. The process of development involves a division of technical and technological capabilities that determine the economic performance.

With respect to innovation capability development, few studies in the previous literature have directly studied transition. Some studies on catch-up provide information on relevant aspects of transition. Lee (2013) finds that short-cycle technologies provide windows of opportunity for latecomer counties to catch up. If the firms in a country overall cannot access the technology, then they are unlikely to gain entry into the industry the technology is used in unless they can innovate a similar technology separately. Even if they have entered an industry, the knowledge base can change with technological changes introduced elsewhere. Malerba and Nelson (2011) find shifting the demands can cause change in the technology regime. Without access to the latest technology, firms in developing countries can fall behind. The latest technology may not be supported by the market in certain countries or firms may have inadequate absorptive capabilities for them or simply fail to follow market demand. The safest way to ensure access to a technology is the ability to create it.

Since there is little research on innovation system transition, let alone its failure, the failure to accumulate knowledge for innovation is considered as one of the main determinants of transition failure. Knowledge differs in other ways as well. The process of spillover from knowledge flows is emphasized in the national innovation system analysis.

The national innovation systems approach considers actors and networks in the innovation system as well as the institutions and policies that affect innovation (table 4-3). Korea was included in Nelson's (1992) early comparative analysis of innovation systems and Thailand has been analyzed several times by Intarakumnerd (2002, 2011). Therefore, this study on the national innovation systems of Korea and Thailand focuses specifically on the types of knowledge and the institutions and linkages that affect them.

Table 4-3: Comparison of neoclassical and innovation systems approaches to economic growth related to innovation

Theoretical approach	Strategic target	Policy instruments	Outcome measure	Gap
Neoclassical	R&D activity to overcome market failure	R&D subsidies, R&D institution creation, educational policy to increase R&D manpower	Optimization of economic growth	Source of economic growth may come from production or innovation gains
Innovation systems	Support of innovation activities, capabilities, and networking to overcome innovation failure	Firm training to increase innovation capabilities, networking programs to increase knowledge flow and lower network costs, support access to foreign knowhow through, and increase user-producer interactions to strengthen demand alignment	Increase innovation outputs and efficiency	Innovation outputs and efficiency is too complex to identify source of innovation gains; ignores production aspects source of technological change, i.e. production

Source: Adapted from Intarakumnerd and Chaminade (2007).

4.3.1. Firms and industrial organizations

Firms in Korea are known to have strong innovation capabilities. As evidenced by the high number of patents they hold, the *chaebols* or family-owned conglomerates are particularly important for the development of capabilities in Korea (Amsden, 1989). The production and innovation capabilities were developed through close interaction and political ties with the government. At the start of the 1980s, public research was responsible for the large majority of patents held in Korea but by the end of the decade, the share had flipped.

In Thailand, a similar family-owned conglomerate structure is common. The largest companies tended to have close ties to the government and other family-owned conglomerates. The largest companies in Thailand are protected from foreign competition in the banking, ICT, and energy sectors, which serve the domestic market. Technological capabilities for production was largely transferred through joint ventures that were required by law for foreign companies to operate in the country until 1999. Through these joint ventures, multinational companies became dominant in many manufacturing sectors including the automobile and electronics industries. The innovation capabilities of these manufacturing companies are known to be weak.

The supplier networks are different in both countries as well. In Korea, the suppliers are often subsidiaries of the same parent company within the *chaebols*. In Thailand, the suppliers closest to the MNC subsidiaries were more likely to be part of the MNC group. The technological capabilities in the MNC groups were passed down from the parent company. The lower tiers of supplier networks, however, tend to be wholly-owned by Thais. The profit margins do not allow for R&D investments.

The associations in both Korea and Thailand are dominated by the large companies that operate in the economies. In Thailand, those sectors with foreign dependence have strong representation in the associations as well.

4.3.2. Universities and research institutes

Korean universities have developed strong capabilities to educate skilled workers as well as produce R&D outputs. There are five Korean universities in the top 100 of the QS World University Rankings 2019. Thai universities are less well represented, with only two university appearing in the top 500 at 271 and 380. While Korean universities have strong industry linkages, Thailand has weaker linkages.

Korean research institutes are also world-renowned. KIST, the most famous, was established in 1966 with just a few foreign-trained researchers that were well-compensated compared to others within the economy. The National Science and Technology Development Agency is the main research institute in Thailand. It was established in 1990. Moreover, its work targeted basic research and was not connected to industry or commercial markets until recently.

4.3.3. Associations

The industrial group associations in Thailand are a form of networks that enable knowledge flow between individuals and firms within an industrial sector. The structure between the two countries is quite similar. Associations are dominated by the large conglomerates. On difference, however, is that the Korean government is more willing to intervene on behalf of smaller companies.

4.4. Institutions and linkages that contributed to capabilities development of Korea and Thailand

4.4.1. STI policies

The STI policies in Korea and Thailand differ significantly. R&D inputs and R&D institution and policies are considered. One of the main aspects of STI policies are the R&D inputs in terms of investment and personnel (table 4-4). The difference in STI inputs are different by magnitude. The number of R&D personnel available in Korea is more than fourfold that of Thailand. R&D investment is also low in Thailand compared to Korea.

Table 4-4: R&D inputs, Korea

	2009		2014	
	Value	Share	Value	Share
R&D Investment (USD millions)	34,156	2.16%	32.82	1.16%
R&D Personnel (FTE)	466,824	100.00%	605,604	100.00%
R&D Researcher (FTE)	323,175	69.23%	437,447	72.23%

Source: OECD STI Indicators, share calculated by author

The R&D spending is different between the two countries (tables 4-4 and 4-5). The public research funding in Thailand is the higher share of investment and personnel. Public funding of R&D is performed by the university sector and the research institutes. The output from the research, however, does not make it to commercialization.

Table 4-5: R&D inputs, Thailand

R&D Personnel, headcount				
	2009		2014	
	Value	Share	Value	Share
All	110,487	100.00%	143,187	100.00%
Private sector	14,687	13.29%	42,247	29.50%
Non-private sector	95,800	86.71%	100,940	70.50%
Private sector, manufacturing	11,413	10.33%	24,718	17.26%

R&D Investment, million USD				
	2009		2014	
	Value	Share	Value	Share
Gross national	661	100.00%	1,955	100.00%
Private sector	272	41.21%	1,061	54.25%
Non-private sector	388	58.79%	894	45.75%
Private sector manufacturing	269	40.75%	784	40.12%

Source: R&D Survey 2017, STI Office of Thailand.

While R&D investment and personnel are required for performing R&D activities, STI policies can also target creation of R&D institutes and universities. In Korea, public research institutes started through government policies. KIST, the main research institute in Korea, was established in 1966 and spun out several other research institutes that specialized in their particular fields. Within a decade, there were research institutes that studied astronomy and space, standards science, geoscience, electrotechnology, and machinery and materials. Although the government was the first to create research institutes, private companies—especially chaebols—have also created their own research institutes such as Samsung and Hyundai. Further, the government clustered research institutes in Daejeon, where it also established its specialized research university KAIST in cooperation with KIST. The clustering of research organizations increased the output of R&D personnel and output. Today, KIST has a wide network with regional and international labs.

In contrast, Thailand has one main research institute, NSTDA, that has largely remained with the same structure it had when it was started. Its subunits focus on basic science in materials, bioscience, electronics, and nanotechnology. While research programs have been established to support industry, the linkages between government labs and industry have not had major successes.

4.4.2. Education policies

Education policies provide the knowledge workers who generate tacit knowledge required for skilled work and patenting. Korea has a highly educated population. Nearly 90% of the population have high school diplomas. Nearly 30% of the population hold bachelor's degrees and 4.5% hold master's degrees. Whereas Korea once produced high levels of vocational workers, the labor market is no longer as dependent on technical workers. Moreover, the targets set for the number of technical workers has been met by the vocation education system.

The education system in Thailand is still largely biased towards vocational education (table 4-6). Thirty-eight percent of secondary graduates are vocational students. Yet, the students are not readily absorbed by the job market and employers are still finding it difficult to fill technical jobs because the types of vocation studies pursued do not have jobs available. Similar to other studies, it is necessary to match vocation education to market demands (Doner and Schneider, 2019). Moreover, some studies find that low-wage workers may trap industries from transitioning (Raj-Reichert, 2019).

Another difference between the two countries is their policy on sending students to study abroad. Korea is the third largest international student body in the United States. Many of the US-trained students return to work in Korea as part of the brain circulation process. Some are even supported by private companies that do not have any work requirements attached. In contrast, Thai students that study abroad are subject to strict conditions upon completion. They must return immediately upon graduation, denying any opportunities to gain work experience. Additionally, they are expected to work for a government agency. This includes PhDs that may not have backgrounds in the ministries to which they are assigned.

Table 4-6: Graduates by education level

Education Level	Korea 2018	Thailand 2015
Secondary education, general	407,600	427,395
Secondary VET graduates	90,921	266,849
Vocational certificate, all	9,317	146,890
Vocational diploma, all	5,944	119,959

Bachelor's degree, all	373,636	265,010
Master's degree, all	85,525	36,653
PhD degree, all	15,274	2,940

Source: Database on Tertiary Education, Korean Educational Statistical Service and Education Statistics, Ministry of Education of Thailand

Note: The data are for the latest years available for the respective countries.

Thailand has almost caught up to Korea in secondary education graduation rates and is rapidly catching up in the graduation rates at the bachelor level (table 4-7). University education in Thailand was largely built on preexisting institutions. It was only in 1990, however, when the first autonomous university was introduced. Technical universities were also established in the 1990s. Other recent policy changes explain how the rate of graduation at all levels has increased so quickly. These universities began granting post-graduate degrees only recently. Education reform enacted in 2013, however, has increased the level of graduates dramatically. But the stock of skilled workers still has a long way to catch up.

Table 4-7: Share of labor force by level of education

	Korea		Thailand	
	1970	2015	1970	2016
Secondary diploma	27.58%	85.72%	5.5%	45.07%
Bachelor's degree	n/a	28.68%	n/a	14.81%
Master's degree	n/a	4.45%	n/a	2.14%
PhD degree	n/a	0.77%	n/a	0.00%

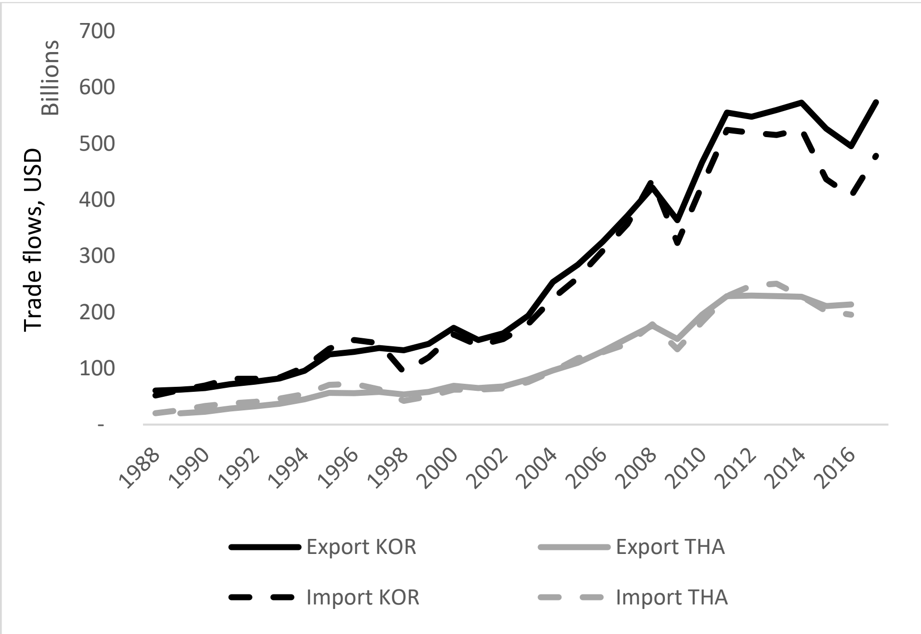
Source: World Development Indicators, World Bank

Note: n/a means data is not available.

4.4.3. Industrial, trade, and investment policies

Institutions and policies in both countries targeted several types of knowledge flows in both Korea and Thailand. Coe and Helpman (1995) suggest that the benefits of trade lead to spillovers for countries. The levels of imports and exports are relatively similar within each country and grew faster in Korea than Thailand (figure 4-2). Embodied knowledge in the goods traded are expected to benefit the economies.

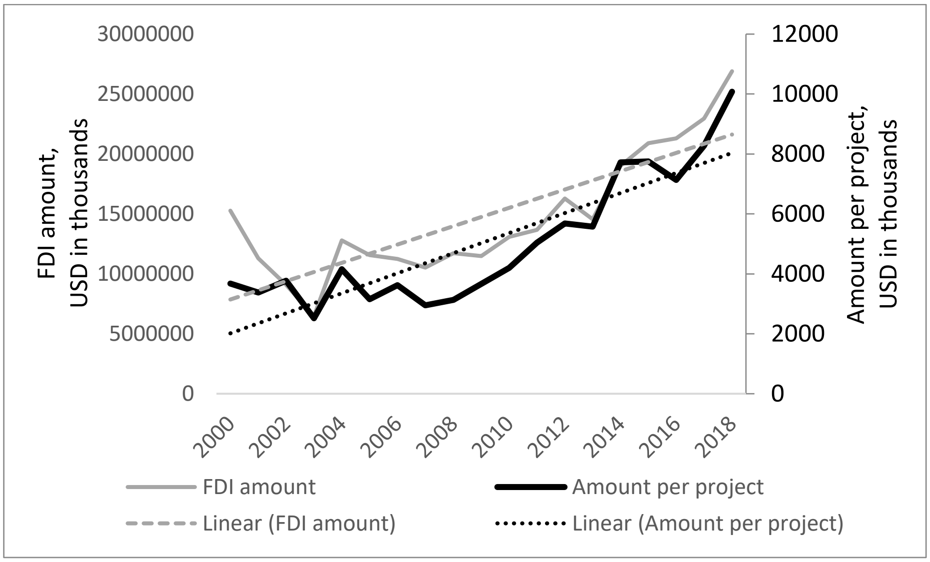
Figure 4-2: Trade flows, Korea and Thailand



Source: International Trade Data, UNCOMTRADE

Despite the lack of impact of inward FDI on productivity found in chapter 2, inward FDI continues to increase in Korea (figure 4-3). Inward FDI towards Korea has increased steadily as has the average size of the projects since 2000 (figure 4-3). Learning occurs through the interaction of skilled human capital and increases the impact of spillovers through trade and FDI (Ali et al., 2016). As shown in chapter 2, embodied knowledge networks represent sources of spillovers into an innovation system. The total inward FDI that Korea receives demonstrates potential inflows of knowledge spillovers. Inward FDI to advanced countries, however, may suggest that technology sourcing is occurring. The acquisitions of some firms by foreign firms recently suggest this is happening. For instance, Tata Motors acquired Daewoo Motors after the Asian Financial Crisis.

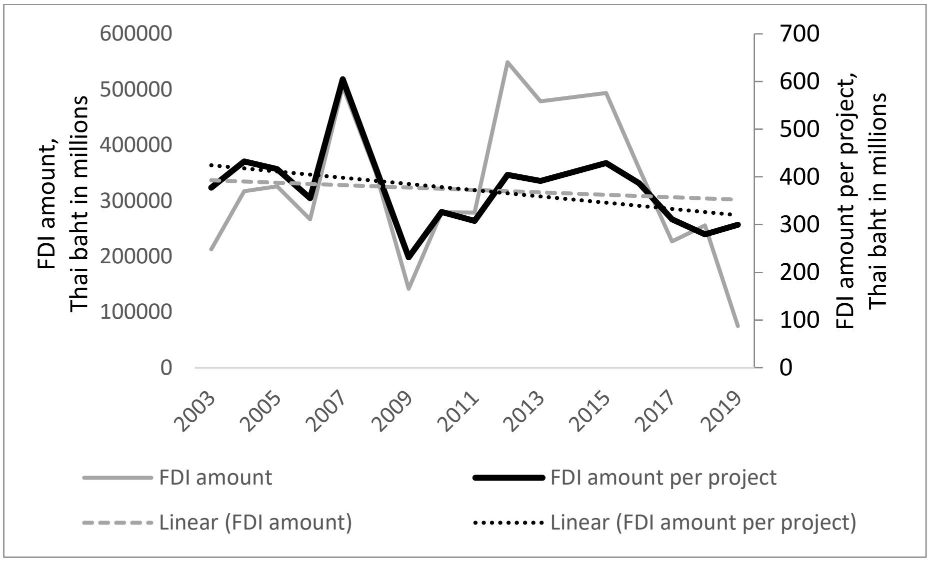
Figure 4-3: Total FDI and average FDI per project in Korea



Source: KOSIS Statistical Database

Since Thailand has weaker learning capabilities, it may be less well-positioned to develop knowledge spillovers from its trade activities. As the results from chapter 2 suggest, FDI provides productivity increases directly through production capabilities rather than knowledge spillovers. Past studies have found that excessive reliance on FDI leads to foreign dominance of sectors (Raj-Reichert, 2019), which seems to have occurred in the automotive and electronic sectors in Thailand. The poorer performance of FDI may account for the fall in inward FDI to the country (figure 4-4).

Figure 4-4: Total inward FDI and average FDI per project in Thailand



Source: FDI Statistics, Board of Investment

Wong (2011) suggests providing rent support to indigenous firms in order to stimulate capability development in national innovation systems. The institutions and policies in Thailand tend to favor foreign MNCs and domestic family-owned corporations through efficiency-seeking strategies to increase productivity and growth. These policies disincentivize development of innovation capabilities because they increase foreign competition and risks posed to entry, ultimately ensuring that domestic firms will fail to survive in the market.

4.5.Discussion

That Korea managed to transition its innovation system can almost be taken for granted at this point but the findings from the previous chapter suggests that the innovation capability development is significant when measured through changes in knowledge networks. The Korean innovation system transition process is instructive when analyzed in comparison to Thailand, since the latter has not managed to transition as successfully. Thailand is still dependent on its production capabilities. That alone does not qualify it for innovation system transition failure. The poor performance of its firms and other actors, however, suggests that it may suffer from transition failure. Another indicator is the mismatch between the students entering the vocational education system and those that end up working in the technical workforce. This suggests an inefficiency of the production system.

The focus of innovation systems studies are the capabilities of the firms because that is where innovation occurs. The main streams through which innovation systems improve is through active government policy engagement as they support how firms' learning capabilities, increase access to foreign knowledge, and increase skilled human capital. The results of the policy are determined by the results of the other aspects. A cursory look at the actors suggest that Korean firms are strong learners and those in Thailand are weak. The means in which policy has increased access to foreign knowledge has been limited to production-oriented knowledge in Thailand. The research institutes in Korea also perform better at creating networks of knowledge that are useful. Universities in Korea have been changed and created to meet new demands for innovation but those in Thailand have remained the same. It is also difficult to attract quality professors in Thailand because monthly salaries start well below 1,000 USD, even at the elite universities.

Korea managed to transition its innovation system by focusing on educating its workforce but at a rate that the workers are able to be absorbed by the labor market. Further, it has made more effective use of its graduates. By targeting STEM education, many manufacturing companies had a strong engineering workforce to draw from. Korean universities and R&D institutes also provided a source of pre-commercial R&D capabilities. The tacit knowledge that was gained in the activities did not lead to commercially viable activities in the market but some immeasurable learning capabilities were developing.

The organization of the industry also enabled accelerated accumulation of knowledge and prevented the loss of existing knowledge stocks. By creating its own national champions, knowledge was retained when it might well have been lost, especially after the Asian Economic Crisis left the firms in the economy vulnerable. Business groups or conglomerates can have different effects on innovation in developing countries (Mahmood and Mitchell, 2004). This effect has an inverted u-shaped relationship, at which point the marginal costs of group share begin to outpace the marginal benefits.

The institutions in Thailand, however, may have retarded the transition of the innovation system to the point of failure. The weakness of the actors in the innovation system has already been established (Intarakumnerd et al., 2002). What this study set out to show is how they remained so weak.

The entry of foreign MNCs in many of the manufacturing sectors made many of the domestic firms in those sectors reliant on FDI, which diminished their abilities to accumulate knowledge necessary for innovation. The costs were reduced for competitors through incentives schemes that domestic firms could not take advantage of because of technological inferiority. At the same time, the risks were raised because the competition they faced was higher than they would have from domestic firms alone.

While R&D support was provided through NSTDA and universities, they were not well-positioned to make use of it. Being at lower tiers of supplier relationships meant that their margins were lower, not allowing for R&D investment. Rather they were expected to fund process efficiency projects to remain in the supply chains of MNCs. Other sectors that are protected for various reasons such as security did not face the typical pressures to engage in R&D for competitive reasons. The largest company in Thailand is PTT, the state-owned energy monopoly. The ICT sector is another example of how government control of competition has delayed technological advancement of infrastructure because the cost to import the technology is too high.

The comparison between Korea and Thailand provide several lessons. First, Thailand should plan long-term for investment in non-industry innovation capabilities, i.e. university and research institutes; They may consider creating new institutions like KIST and KAIST to escape the hold that any vested interests may have on the long-established university systems.

Second, Thailand can consider creating an innovation “sandbox.” KIST was created using a small number of researchers relative to the size of the population. The resources it was given, however, was much larger than other comparable institutions received. Yet, the implication of such a strategy needs to aim for greater innovation output. Innovation systems demonstrate small world properties, which suggest that a small number of patents provide the majority of value (Cowan and Jonard, 2004). The need for quality control is high because the increased rents provided may also increase risk of corruption. Risk management strategies should be employed in tandem.

Third, a mechanism is needed to communicate the labor market demands to students entering the education system. Many choose to study management but there is a glut of graduates that have difficulty finding employment.

Finally, the complementarity or alignment of institutions are an important aspect of the national innovation system that should be considered (Amable, 2000). The findings from the previous two chapters suggest that this is one of the sources of Korea's success as well as Thailand's failure to transition their innovation systems. The productivity of Korean industries has shifted from production to innovation-based sources of growth. In Thailand, however, the emphasis of its institutions seems to be on disembodied knowledge flows rather than embodied knowledge flows but the scale of the effects fails to generate productivity growth overall. When the scale of productivity and research stocks are considered in chapter 2, the focus of innovation-driven institutions seems be on disembodied knowledge flows across industrial sectors.

The reasons for the misalignment can be found in how incentive structures are formed in the innovation system. The dominance of MNCs and their relationship with large, local business groups shifts resources towards these same companies. Investment policies that favor large companies and foreign sources are the predominant form of industrial policy. The actors that have been formed reinforce rather than counterbalance this bias. Industrial associations provide platforms to influence policymaking and are led by these same actors.

Additionally, the innovation-related aspects of the innovation system are also indirectly weakened by existing institutions. The late formation of intellectual property rights protections in Thailand made it impossible for actors to even navigate knowledge embodied in patents let alone craft related institutional incentives. This affected the ability of firms to accumulate knowledge and for human resource development to develop the necessary skilled individuals to generate tacit knowledge required for knowledge production.

Chapter 5.
Conclusion

5.1. Summary

Most studies on national innovation systems focus on advanced countries that tend to leave out drivers of productivity and economic growth for developing countries (cf. Guan and Chen, 2012). Developing countries at the lower ranges of income must, thus, find ways to transition to innovation-based with few reliable models to follow. This study represents an exploratory work because there have not been previous studies on innovation transition failure in the past. This dissertation focused on the potential causes of innovation system transition and by extension its failure. Since knowledge accumulation drives innovation, the three studies focus on measuring knowledge accumulation through different types of knowledge flows and networks and identifies the determinants and institutions of accumulation of the different types of knowledge.

Chapter 2 is a quantitative study that examines the effects of different types of knowledge flows on the productivity growth of two different types of economies: a national innovation system that has successfully transitioned, i.e. Korea, and a national innovation system that has failed to transition, i.e. Thailand. In Korea, foreign sources of production capabilities, via inward FDI, do not have positive effects on productivity growth. Instead, Korean industrial sectors are driven by innovation capabilities that are dependent on R&D activity and its related spillovers. Embodied knowledge flows are the significant source of productivity growth across economic sectors. In Thailand, production capabilities are still the one of main drivers of growth. Embodied knowledge flows through industrial sector R&D activity have a significant and positive effect on productivity. When the scale of productivity and research stocks are considered, however, the emphasis of innovation-driven institutions shifts to disembodied knowledge flows. Thus, the alignment of the institutions does not seem to lead to consistent outcomes on productivity. Thus the scale and efficiency of learning through R&D need to be increased across the industrial sectors, especially through channels of embodied knowledge flows.

Chapter 3 presents a study that takes a double-sided approach in examining the industrial sectors in Korea and Thailand. First, a network analysis approach is used to provide a snapshot of the strength of two main flows of knowledge networks in the sectoral innovation systems: embodied and disembodied. The embodied and disembodied networks show the relative strengths of knowledge flows in the transportation sectors in each country. The knowledge networks in Korea are stronger, and they have also strengthened over time when measured by at the economic and technological systems and subsystems. The knowledge networks in Thailand present a more ambiguous outcome. The change in disembodied knowledge flows is significant while that of embodied knowledge flows depends on the relativization process. This aligns with the findings from the chapter, which suggests that productivity is significantly affected by changes in the rate of disembodied knowledge flow. Increasing the scale of the impacts, however, may be difficult.

The second part of chapter 3 examines the sectoral innovation system to understand the dynamics of institutional change. The actors at the top of the industries within the systems have remained the same in both countries with most firms exiting at the bottom, which should be expected. From a global perspective, however, the difference in catch up is quite different. Hyundai is the only remaining Korean automaker but it is also one of the top global carmakers. Its emergence and survival are based largely on its innovation capabilities that were nurtured by institutions within in the sectoral innovation system. In contrast, the top firms in the auto industry of Thailand are still foreign MNCs that have continued to consolidate the market through foreign innovation capabilities. The main difference in performance is found in the incentive structure that is created for technological capabilities. Whereas in Korea, institutions in the innovation system targeted incentives for innovation, the institutions are heavily biased towards production.

Chapter 4 turns to a national perspective. Taking a national innovation systems perspective, the innovation system institutions also affect incentives of actors regarding technological capabilities. Korea has managed to develop globally competitive firms with strong innovation capabilities in several industries, e.g. Hyundai, Samsung, and LG. In Thailand, the lack of innovation system transition is taken as an underlying cause of the middle-income trap in Thailand. Similar to the auto sector examined in chapter 3, MNCs dominate the manufacturing sectors for similar reasons. The sectors where the largest companies operate in Thailand are protected from competition, disincentivizing development of innovation capabilities. The national innovation system has had weak actors (Intarakumnerd et al., 2002) that have not markedly changed. The study finds that the institutions and policies that affect knowledge accumulation in Thailand were late to form and even slowed the process of accumulation.

5.2.Implications

The implications for the studies in this dissertation focus on the types of knowledge that drive innovation capabilities. Variation between the sources of productivity growth by knowledge type is an important aspect of innovation transition and therefore growth. The institutional incentive structures are separate for the different types of innovation capabilities. Increasing production capabilities does not lead to improved incentives for innovation capabilities, and the same may be true of embodied and disembodied knowledge networks. In fact, institutions may compete with each other when resources are limited. While types of innovation capabilities increase complexity, part of the complexity is that new capabilities must be added to existing capabilities, increasing management complexity.

Moreover, the alignment of institutions and the types of knowledge accumulation are important. In Korea, the development of embodied knowledge absorbing capabilities are significant across sectors. Those in Thailand, however, are not. In fact, Thailand seems to be pursuing disembodied knowledge accumulation that may be difficult to actualize without leading domestic firms in the industrial structure of the economy. In other words, patent ownership is an important aspect of a patent targeting strategy. Additionally, how policy can increase the scale of R&D expenditures or change the economic structure is uncertain. The realignment of institutions that relate to trade and economic structure increases the risk of upsetting incumbents that may be vested in the existing structure and institutions.

Further implications are that government policies can be used to encourage “artificial” demand for knowledge capital and knowledge workers by supporting their development. Since R&D expenditure is already targeted, policies may try to find ways to increase the knowledge workers more efficiently and rapidly in the Thai economy while maintaining research quality. When establishing the flagship research institute KIST in 1966, Korea managed to recruit a small number of US-trained PhDs by providing higher salaries relative to the national average and provided appropriate research facilities. In contrast, the current scholarship program in Thailand makes inefficient use of its study abroad support. Students must return immediately upon completion of studies, missing the opportunity to gain further high-skills training abroad and forcing them to take jobs that do not apply their advanced human capital.

5.3. Limitations and future research

One of the main limitations of the study stem from data availability in Thailand, similar to many developing countries. Yet, a small batch of data recently became available for Thailand. If additional data becomes available, more advanced modeling techniques can be applied. As a result, the comparison was limited to Thailand and Korea. Yet, the inclusion of more advanced countries, and even lesser developed countries, would not change the relative positions that were found. The differences may be finer but the result would be the same. Another impact of data availability is that the time period studied was rather short in the empirical study. The present-day innovation systems, however, are the result of past history and unlikely to have dramatically been different from the results studied. Lastly, the differences in characteristics of the patenting systems in the two countries include variations in patent quality that are not captured in the data used to construct the knowledge networks. The patent quality, however, is assumed to be higher in Korea than in Thailand. Using a common patent system, e.g. EPO or USPTO, would likely make the differences starker in favor of Korea over Thailand.

Bibliography

Abramovitz, M. (1986). “Catching Up, Forging Ahead, and Falling Behind.” *The Journal of Economic History* 46(2): 385-406.

Acemoglu, D., P. Aghion, and F. Zabiotti. (2006). “Distance to Frontier, Selection, and Economic Growth.” *Journal of the European Economic Association* 4(1): 37-74.

Agénor, P.-R. (2017). “Caught in the Middle? The Economics of Middle-Income Traps.” *Economic Surveys*: 1-21.

Agénor, P.-R. and O. Canuto, (2015). “Middle-income growth traps.” *Research in Economics* 69: 641–660.

Aghion, P. and P. Howitt. (1992). “A Model of Growth Through Creative Destruction.” *Econometrica* 60(2): 323-351.

Aiyar, S., D. Duval, D. Puy, Y. Wu, and L. Zhang. (2013). “Growth Slowdowns and the Middle-Income Trap.” IMF Working Paper WP/13/71. IMF.

Akamatsu, K. (1962). “Historical Pattern of Economic Growth in Developing Countries.” *The Developing Economies* 1: 3–25.

Ali, M., U. Cantner, and I. Roy. (2016). “Knowledge Spillovers Through FDI and Trade: The Moderating Role of Quality-Adjusted Human Capital.” *Journal of Evolutionary Economics* 26(4): 837–868.

Allison, P.D. (2012). "When Can You Safely Ignore Multicollinearity?" Statistical Horizons accessed at https://statisticalhorizons.com/ on 21 June 2019

American Automobile Manufacturers Association (1996). Facts and Figures.

Amsden, A.H. (1989). *Asia's Next Giant: South Korea and Late Industrialization*. Oxford University Press.

Arrow, (1962). “The Economic Implications of Learning by Doing.” *Review of Economic Studies* 29(3): 155–173.

ASEAN Automotive Federation. (online). Statistics. Retrieved on 6 December 2014 from http://www.asean-autofed.com/statistics.html

Azariadis, C. and A. Drazen, (1990). "Threshold Externalities in Economic Development." *The Quarterly Journal of Economics* 105(2): 501–526.

Barro, R.J. and X. Sala-i-Martin. (1997). "Technological Diffusion, Convergence, and Growth." *Journal of Economic Growth* 2(1): 1-27.

Barthelemy, M., A. Barrat and R. Pastor-Satorras (2005) Characterization and Modeling of Complex Weighted Networks. *Physica A*, 346, 34–43.

Baumol, W.J. (1986). "Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show." *The American Economic Review* 76(5): 1072-1085.

Beckert, J. (2010). "Institutional Isomorphism Revisited: Convergence and Divergence in Institutional Change." *Sociological Theory* 28(2): 150-166.

Bell, D. (1973). *The Coming of Post-industrial Society: A Venture in Social Forecasting*. New York: Basic Books.

Bell, M. and K. Pavitt. (1993). "Technological Accumulation and Industrial Growth: Contrasts between Developed and Developing Countries." *Industrial and Corporate Change* 2(2): 157–210.

Bertchek, I. (1995). "Product and Process Innovation as a Response to Increasing Imports and Foreign Direct Investment." *The Journal of Industrial Economics* 43(4): 341-357.

Bien, Y.-H., Y.-M. Su, Y.-C. Wang, C.-H. Chang and Z. Ming-Ru. (2016). "Study on Dynamic Factors Striding Across the Middle Income Trap-Transnational Empirical Analysis Based on Quartile Regression." *Journal of Statistics and Management Systems* 19(1): 107-118.

Binz, C. and B. Truffer, (2017). "Global Innovation Systems—A Conceptual Framework for Innovation Dynamics in Transnational Contexts." *Research Policy* 46: 1284-1298.

Bleda, M. and P. del Rio. (2013). "The Market Failure and the Systemic Failure Rationales in Technological Innovation Systems." *Research Policy* 42: 1039-1052.

Board of Investment (BoI). (2004). Top 10 Exports. *Thailand Investment Review*.

Board of Investment (BoI). (2007). "BoI to Promote Eco-Cars Maximum Incentives for Integrated Car Assembly and Key Parts Manufacturing Projects." Press release, No 87/2 / 2007 (O.41/2).

Branstetter, L. (2001). "Are Knowledge Spillovers International or Intranational in Scope? Microeconometric evidence from the U.S. and Japan." *Journal of International Economics* 53: 53–79

Breschi, S. and F. Malerba. (1997). "Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries." In C. Edquist (ed.) *Systems of Innovation: Technologies, Institutions and Organizations.* Oxon, UK: Routledge.

Buckley, P.J., and N. Hashai. (2014). "The Role of Technological Catch Up And Domestic Market Growth in the Genesis of Emerging Country Based Multinationals." *Research Policy* 43: 423– 437

Bulman, D., M. Eden, and H. Nguyen. (2017). "Transitioning from low-income growth to high-income growth: is there a middle-income trap?" ADB Working Paper No. 646.

Campbell, M.J. and T.D.V. Swinscow. (2002). *Statistics at Square One* (11th ed.). West Sussex, UK: Wiley-Blackwell.

Carlsson, B. 1983. "Industrial Subsidies in Sweden: Macro-Economic Effects and an International Comparison." *The Journal of Industrial Economics* 32(1): 1-23.

Carlsson, B. and R. Stankiewicz. (1991). "On the Nature, Function, and Composition of Technological Systems." *Journal of Evolutionary Economics*: 93-118.

Chang, P.-L. and H.-Y. Shih (2005) Comparing Patterns of Intersectoral Innovation Diffusion in Taiwan and China: A Network Analysis. *Technovation*, 25,155–169.

Choung, J.-Y. H.-R. Hwang, and J. Choi. (2016). "Post Catchup System Transition Failure: The Case of ICT Technology Development in Korea." *Asian Journal of Technology Innovation* 24(sup1): 78-102.

Choung, J.-Y., H.-R. Hwang, and J.H. Choi. (2000). "Transition of Latecomer Firms from Technology Users to Technology Generators: Korean Semiconductor Firms." *World Development* 28(5): 969-982.

Christensen, S, D. Dollar, A. Siamwalla, and P. Vichyanond. (1993). *Thailand - The Lessons of East Asia: The Institutional and Political Underpinnings of Growth.* Washington, DC: The World Bank.

Cirera, X. and W.F. Maloney (2017). *The Innovation Paradox: Developing-Country Capabilities and the Unrealized Promise of Technological Catch-Up*. Washington, DC: World Bank.

Coe, D.T. and E. Helpman. (1995). "International R&D spillovers." *European Economic Review* 39: 859-887.

Cohen, W.M. and D.A. Levinthal, (1990). "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* 35(1): 128-152.

Cohen, W.M. and D.A. Levinthal. (1989). "Innovation and Learning: The Two Faces of R&D." *The Economic Journal* 99: 569-596.

Cooke, P., M. Gomez Uranga, and G. Etxebarria. (1997). "Regional Innovation Systems: Institutional and Organizational Dimensions." *Research Policy* 26: 475-491.

Cowan, R. and N. Jonard. (2004). "Network Structure and the Diffusion of Knowledge." *Journal of Economic Dynamics & Control* 28: 1557-1575.

Cusumano, M.A. (1988). "Manufacturing Innovation: Lessons From The Japanese Auto Industry." *Sloan Management Review* 30(1): 29-39.

Dabús, C., F. Tohmé, and M.A. Caraballo. (2016). "A Middle Income Trap in a Small Open Economy: Modeling the Argentinian Case." *Economic Modelling* (53): 436-444.

DeBresson, C. (1996a). "The Inter-industrial Analysis Of Innovative Activities." In C. DeBresson (ed.), *Economic Interdependence and Innovative Activity. An Input-Output Analysis*. Edward Elgar, Cheltenham, 66–78.

DeBresson, C. (1996b). "Why Innovative Activities Cluster." In C. DeBresson (ed.), *Economic Interdependence and Innovative Activity. An Input-Output Analysis*. Edward Elgar, Cheltenham, 149–165.

Dedrick, J., K.L. Kraemer and G. Linden (2010). "Who Profits from Innovation in Global Value Chains?: A Study of the Ipod and Notebook PCs." *Industrial and Corporate Change* 19(1): 81-116.

Dietzenbacher, E. and B. Los (2002) "Externalities of R&D Expenditures." *Economic Systems Research* 14: 407–425.

Doner, R. and B.R. Schneider (2019). "Technical Education in the Middle Income Trap: Building Coalitions for Skill Formation." *The Journal of Development Studies*: (online).

Doner, R.F. (1991). *Driving a Bargain: Automobile Industrialization and Japanese Firms in Southeast Asia*. Berkeley, CA: University of California Press.

Doner, R.F. (2009). "Chapter 7: Automobiles." *The Politics of Uneven Development: Thailand's Economic Growth in Comparative Perspective*. Cambridge University Press.

Dosi, G. 1982. "Technological Paradigms and Technological Trajectories." *Research Policy* 11: 147-162.

Dougherty, S.M., R. Inklaar, R.H. McGuckin, and B. van Ark. (2008). "International Comparisons of R&D Expenditure: Does an R&D PPP Make a Difference? Working Paper 12829, National Bureau of Economic Research, Cambridge, MA.

Economist, The. (2013). "Thailand Cars: Boom Times for the "Detroit of South-east Asia." September 10, 2013.

Edquist, C. (2006). *Systems of Innovation: Perspectives and Challenges. In The Oxford Handbook of Innovation*. J. Fagerberg, D.C. Mowery, and R.R. Nelson (Eds.). Oxford University Press.

Edquist, C. (ed.) (1997). *Systems of Innovation. Technologies, Institutions and Organisations*. London: Pinter Publishers.

Edquist, C. and M. McKelvey. (eds.) (2000) *Systems of Innovation: Growth, Competitiveness and Employment*. Cheltenham, UK: Edward Elgar.

Eichengreen, B., D. Park, and K. Shin. (2014). "Growth Slowdowns Redux." *Japan and the World Economy* 32: 65–84.

Eisenhardt, K.M. and J.A. Martin. (2000). “Dynamic Capabilities: What Are They?” *Strategic Management Journal* 21: 1105–1121.

Etzkowitz, H. and L. Leydesdorff. (2000). “The Dynamics of Innovation: From National Systems and ‘‘Mode 2’’ to a Triple Helix of University–industry–government Relations.” *Research Policy* 29: 109–123

Ernst, D. (2002). “Global Production Networks and the Changing Geography of Innovation Systems. Implications for Developing Countries.” *Economics of Innovation and New Technology* 11(6): 497-523.

Ernst. D. (1998). “Catching-up Crisis and Industrial Upgrading: Evolutionary Aspects of Technological Learning in Korea's Electronics Industry.” *Asia Pacific Journal of Management* 15(2): 247–283.

Fagerberg, J. (2000). “Technological Progress, Structural Change and Productivity Growth: A Comparative Study.” *Structural Change and Economic Dynamics* 11: 393–411

Falvey, R., N. Foster, and D. Greenaway. (2004). “Imports, Exports, Knowledge Spillovers and Growth.” *Economics Letters* 85: 209–213.

Felipe, J., U. Kumar, and R. Galope. (2014). “Middle-Income Transitions: Trap or Myth?” Working Paper No. 421. Asian Development Bank.

Foxley, A. and F. Sossdorf. (2011). “Making the Transition from Middle-Income to Advanced Economies.” Carnegie Endowment Working Paper.

Freeman, C. (1987). *Technology and Economic Performance: Lessons from Japan.* London: Pinter.

Freyssenet, M. (2009). *The Second Automobile Revolution: Trajectories of the World Carmakers in the 21st Century*. London: Palgrave McMillan.

Fu, X., C. Pietrobelli, and L. Soete. (2011). “The Role of Foreign Technology and Indigenous Innovation in the Emerging Economies: Technological Change and Catching-up.” *World Development* 39(7): 1204-1212.

Gerschenkron, A. (1962). *Economic Backwardness in Historical Perspective*. New York: Frederick A. Praeger Publishers.

Giachettia, C., and G. Marchi. (2017). “Successive Changes in Leadership in the Worldwide Mobile Phone Industry: The Role of Windows of Opportunity and Firms’ Competitive Action.” *Research Policy* 46(2): 352-364.

Gill, I.S. and H. Kharas. (2007). “An East Asian Renaissance: Ideas for Economic Growth.” World Bank.

Grant, R.M. (1991). “The Resource-based Theory of Competitive Advantage: Implications for Strategy Formulation.” *California Management Review* 33(3): 114-135.

Griliches, Z. (1979). “Issues in Assessing the Contribution of Research and Development to Productivity Growth.” *The Bell Journal of Economics* 10(1): 92-116.

Griliches, Z. (1992). “The Search for R&D Spillovers.” *The Scandinavian Journal of Economics* 94: 29-47.

Gu, S. (1999). “Implications of National Innovation Systems for Developing Countries: Managing Change and Complexity in Economic Development.” UNU/INTECH Discussion Papers No. 9903.

Guan, J. and K. Chen. (2012). “Modeling the Relative Efficiency of National Innovation Systems.” *Research Policy* 41: 102– 115.

Guo, L., M. Yue Zhang, M. Dodgson, D. Gann, and H. Cai. (2018). “Seizing Windows of Opportunity by Using Technology-Building and Market-Seeking Strategies in Tandem: Huawei’s Sustained Catch-Up in the Global Market.” *Asia Pacific Journal of Management*: 1-31.

Hair, J.F., Anderson, R.E., Tatham, R.L., and Black, W.C. (1995). *Multivariate Analysis with Readings.* Upper Saddle River, NJ: Prentice Hall.

Han, X. and S-J. Wei. (2015). “Re-Examining the Middle-Income Trap Hypothesis (MITH): What to Reject and What to Revive?” Working Paper No. 436. Asian Development Bank.

Hanel, P. (2000) R&D, Interindustry and International Technology Spillovers and the Total Factor Productivity Growth of Manufacturing Industries in Canada, 1974–1989. *Economic Systems Research*, 12, 345–361.

Hausmann, R., L. Pritchett, and D. Rodrik. (2005). “Growth Accelerations.” *Journal of Economic Growth* 10: 303–329.

Hill, H., T.S. Yean, and R.H.M. Zin. (2012). "Malaysia: A Success Story Stuck in the Middle?" *The World Economy* 35(12): 1687–1711.

Hoai, D.T.T., F. Tarp, D. van Seventer, and H.C. Hoa. (2016). "Growth and Structural Transformation in Viet Nam During the 2000s." Working Paper 2016/108. UNU-WIDER.

Hoai, D.T.T., F. Tarp, D. van Seventer, and H.C. Hoa. (2016). "Growth and Structural Transformation in Viet Nam During the 2000s." Working Paper 2016/108. UNU-WIDER.

Hobday, M. (1995). "East Asian Latecomer Firms: Learning the Technology of Electronics." *World Development* 23(7): 1171-1193.

Hobday, M. (2003). "Innovation in Asian Industrialization: A Gerschenkronian Perspective." *Oxford Development Studies* 31(3): 293-314.

Hobday, M. and H. Rush. (2007). "Upgrading the Technological Capabilities of Foreign Transnational Subsidiaries in Developing Countries: The Case of Electronics in Thailand." *Research Policy* 36(9): 1335-1356.

Hobday, M., H. Rush, and J. Bessant. (2004). "Approaching the Innovation Frontier in Korea: The Transition Phase to Leadership." *Research Policy* 33: 1433–1457.

Hu, M.-C. and S.-C. Hung. (2014). "Taiwan's Pharmaceuticals: A Failure of the Sectoral System of Innovation?" *Technological Forecasting & Social Change* 88: 162–176.

Hwang, W.-S. and J.-D. Lee. (2014). "Interindustry Knowledge Transfer and Absorption via Two Channels: The Case of Korea." *Global Economic Review*. 43(2): 131-152.

Im, F.G. and D. Rosenblatt. (2015). "Middle-Income Traps: A Conceptual and Empirical Survey." J*ournal of International Commerce, Economics and Policy* 6(3).

Imbs, J. and R. Wacziarg, (2003). "Stages of Diversification." *The American Economic Review* 93(1): 63-86.

Inatarakumnerd, P. and C. Chaminade. (2007). "Strategy Versus Practice in Innovation Systems Policy: The Case of Thailand." *Asian Journal of Technology Innovation* 15(2): 197-213.

Intarakumnerd, P. and C. Chaminade (2011). "Innovation Policies in Thailand: Towards a System of Innovation Approach?" *Asia Pacific Business Review* 17(2): 241-256.

Intarakumnerd, P. and P. Chaoroenporn. (2013). "The Roles of Intermediaries in Sectoral Innovation System in Developing Countries: Public Organizations Versus Private Organizations." *Asian Journal of Technology Innovation.* 21(1): 108-119 .

Intarakumnerd, P. and T. Virasa. (2004). "Government Policies and Measures in Supporting Technological Capability Development of Latecomer Firms: A Tentative Taxonomy." *Asian Journal of Technology Innovation* 12(2): 1-19.

Intarakumnerd, P., N. Gerdsri and P. Teekasap. (2012). "The Roles of External Knowledge Sources in Thailand's Automotive Industry." *Asian Journal of Technology Innovation* 20(S1): 85–97.

Intarakumnerd, P., N. Gerdsri, and P. Teekasap. (2011). "Enhancing Innovation Capability Using Local Universities and Public Research Institutes as External Resources: Thailand's Experiences," in Sunami, A. and P. Intarakumnerd, (eds.), *A Comparative Study on the Role of University and PRI as External Resources for Firms' Innovation*. ERIA Research Project Report 2010-10, Jakarta: ERIA: 1-56.

Intarakumnerd, P., P. Chairatana, and t. Tangchitpiboon. (2002). "National Innovation System in Less Successful Developing Countries: The Case of Thailand." *Research Policy* 31: 1445-1457.

Intarakumnerd. P. and M. Fujita. (2009). "China's Threat and Opportunity for Thai and Vietnamese Motorcycle Industries: A Sectoral Innovation System Analysis." *Science, Technology, and Society* 31(1): 35-60.

Jaccobson, S. and A. Bergek (2006). "A Framework for Guiding Policy-makers Intervening in Emerging Innovation Systems in 'Catching-Up' Countries." *The European Journal of Development Research* 18(4): 687–707.

Jaffe, A.B. (1986). "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits and Market Value." *American Economic Review*. 76: 984–1001.

Jato Dynamics, Ltd. (2018). "Global Car Sales up by 2.4% in 2017 due to Soaring Demand in Europe, Asia-Pacific and Latin America." Press Release. 20 February 2018. Accessed at https://www.jato.com/wp-content/uploads/2018/02/2017-Global-Sales-Release-Final.pdf.

Jimenez, E., Nguyen, V. and Patrinos, H. A. (2012). "Stuck in the Middle? Human Capital Development and Economic Growth in Malaysia and Thailand." Policy Research Working Paper No. 6283. World Bank.

Jitsuchon, S. (2012). "Thailand in a Middle-income Trap." *TDRI Quarterly Review* 27(2): 13–20.

Johnson, D. (2002). "The OECD Technology Concordance (OTC): Patents by Industry of Manufacture and Sector of Use." OECD Science, Technology and Industry Working Papers No. 2002/05. Paris: OECD Publishing.

Kang H. and J. Song. (2017). "Innovation and Recurring Shifts in Industrial Leadership: Three Phases of Change and Persistence in the Camera Industry." *Research Policy* 46(2): 367-387.

Kang, B., K. Nabeshima, and F-T. Cheng. (2015). "Avoiding the Middle-Income Trap: Indigenous Innovative Effort vs. Foreign Innovative Effort." Discussion Paper No. 509. Institute of Developing Economies, JETRO, Japan.

Kaplan, E.L., and P. Meier. (1958). "Nonparametric Estimation from Incomplete Observations." *Journal of the American Statistical Association* 53:457-481.

Ketels, C.H.M. and O. Memedovic. (2008). "From Clusters yo Cluster-Based Economic Development." *International Journal of Technological Learning, Innovation and Development* 1(3): 375-392.

Kim, J.W. and H.K. Lee. (2004). "Embodied and Disembodied International Spillovers of R&D in OECD Manufacturing Industries." *Technovation* 24: 359–368.

Kim, K., Y. Choi, C.Y. Choi, H.J. Kim. (2010). "The Role of Intermediaries on Technological Risk Management and Business Development Performance in Korea." *Technological Forecasting & Social Change* 77: 870-880.

Kim, L. (1980). “Stages Of Development Of Industrial Technology in a Developing Country: A Model.” *Research Policy* 9: 254-277.

Kim, L. (1997). *Imitation to Innovation: The Dynamics of Korea's Technological Learning.* Harvard Business School Press.

Kim, L. (1998). “Technology Policies and Strategies for Developing Countries: Lessons from the Korean Experience.” *Technology Analysis & Strategic Management*. 10(3): 311-324.

Klepper, S. (1997). “Industry Life Cycles.” *Industrial and Corporate Change* 6(1): 145-182.

Kogut, B. and S.J. Chang. (1991). “Technological Capabilities and Japanese Foreign Direct Investment in the United States.” *The Review of Economics and Statistics* 73(3): 401-413.

Kogut, B. and U. Zander. (1993). “Knowledge of the Firm and the Evolutionary Theory of the Multinational Corporation.” Journal of International Business Studies.Koopman, R., W. Powers, Z. Wang, and S.-J. Wei. (2000). “Give Credit where Credit Is Due: Tracing Value Added in Global Production Chains.” NBER Working Paper Series No. 16426.

Kohpaiboon, A. (2006). “Foreign Direct Investment and Technology Spillover: A Cross-industry Analysis of Thai Manufacturing.” *World Development* 34(3): 541–556.

Kortum, S. and J. Putnam, (1997). “Assigning Patents to Industries: Tests of the Yale Technology Concordance.” *Economic Systems Research* 9(2): 161-176.

KPMG International. (2018). Global Automotive Executive Survey 2018.

Krugman, P. (1994). The Myth of Asia’s Miracle. *Foreign Affairs* 73(6).

Kumagai, S. (2015). “The Middle-Income Trap from the Viewpoint of Trade Structures: Are the Geese Trapped or Still Flying?" Journal of International Commerce, Economics and Policy 6(3).

Kuznets, S. (1955). “Economic Growth and Income Inequality.” *American Economic Review* 49: 1-28.

Lall, S. and M. Teubal. (1998). "'Market-Stimulating' Technology Policies in Developing Countries: A Framework with Examples from East Asia." *World Development* 26(8): 1369-1385.

Lall, S. (1992). "Technological Capabilities and Industrialization." *World Development* 20(2): 165-186.

Lall, S. (2000). "Technological Change and Industrialization in the Asian Newly Industrializing Economies: Achievements and Challenges," in L. Kim and R.R. Nelson (eds.), *Technology, Learning and Innovation: Experiences of Newly Industrializing Economies*. Cambridge, UK: Cambridge University Press.

Lall, S. (2001). "National Strategies for Technology Adoption in the Industrial Sector: Lessons of Recent Experience in the Developing Regions." Background paper for the *UN Human Development Report 2001: Harnessing Technology for Human Development*.

Lee, E.Y., and B.C. Cin. (2010). "The Effect of Risk-Sharing Government Subsidy on Corporate R&D Investment: Empirical Evidence from Korea." *Technological Forecasting & Social Change* 77: 881–890.

Lee, C.-Y. (2010). "A Theory of Firm Growth: Learning Capability, Knowledge Threshold, and Patterns of Growth." *Research Policy* 39: 278–289.

Lee, J.-D., C. Baek, S. Maliphol, and J.-I. Yeon. (2019). "Middle Innovation Trap." *Foresight and STI Governance* 13(1): 6–18.

Lee, K. (2005). "Making a Technological Catch-up: Barriers and Opportunities." *Asian Journal of Technology Innovation* 13(2): 97-131.

Lee, K. (2013). *Schumpeterian Analysis of Catch-up: Knowledge, Path-Creation, and the Middle-Income Trap*. Cambridge, UK: Cambridge University Press.

Lee, K. and C.-S. Lim. (2001). "Technological Regimes, Catch-up, and Leapfrogging: Findings from the Korean Industries." *Research Policy* 30(3): 459-483.

Lee, K. and F. Malerba. (2017). "Catch-up Cycles and Changes in Industrial Leadership: Windows of Opportunity and Responses of Firms and

Countries in the Evolution of Sectoral Systems." *Research Policy* 46(2):

Lee, K. and J. Ki. (2017). "Rise of Latecomers and Catch-Up Cycles in the World Steel Industry." *Research Policy* 46(2): 365-375.

Lee, K. and B.-Y. Kim. (2009). "Both Institutions and Policies Matter but Differently for Different Income Groups of Countries: Determinants of Long-Run Economic Growth Revisited." *World Development* 37(3): 533–549.

Lee, K. and J.A. Mathews. (2010). "From Washington Consensus to BeST Consensus for world development." *Asian Pacific Economic Literature* 24(1): 86-103.

Lee, K., M. Szapiro and Z. Mao. (2018). "From Global Value Chains (GVC) to Innovation Systems for Local Value Chains and Knowledge Creation." *The European Journal of Development Research* 30(3): 424–441.

Leoncini, R. (1998) "The Nature of Long-run Technological Change: Innovation, Evolution and Technological Systems." *Research Policy* 27: 75–93.

Leoncini, R. and S. Montresor (2003a) The Technological System. In R. Leoncini and S. Montresor (eds.), *Technological Systems and Intersectoral Innovation Flows*. Cheltenham, Edward Elgar, 33–49.

Leoncini, R. and S. Montresor (2005). "Accounting for Core and Extra-Core Relationships in Technological Systems: A Methodological Proposal." *Research Policy*, 34, 83–100.

Leoncini, R. and S. Montresor. (2000a). "Classifying Technological Systems: An Empirical Application to Eight OECD Countries." In P. Saviotti and B. Nooteboom (eds), *Technology and Knowledge: from the Firm to Innovation Systems*. Cheltenham, Edward Elgar, 152–173.

Leoncini, R. and S. Montresor. (2000b). "Network Analysis of Eight Technological Systems." *International Review of Applied Economics* 14: 213–234.

Leoncini, R., A. Maggioni and S. Montresor. (1996). "Intersectoral Innovation Flows and National Technological Systems: Network Analysis for Comparing Italy and Germany." *Research Policy* 25: 415–430.

Lewis, A. (1954). "Economic Development with Unlimited Supplies of Labour." *The Manchester School* 22(2): 139–191.

Lim, C, Y. Kim, and K. Lee. (2017). "Changes in Industrial Leadership and Catch-Up by Latecomers in Shipbuilding Industry." *Asian Journal of Technology Innovation* 25(1): 61-78.

Lin, B.-W. and C.-J. Chen. (2006). "Fostering Product Innovation in Industry Networks: The Mediating Role of Knowledge Integration." *The International Journal of Human Resource Management* 17(1): 155-173.

Lindstrom, T. (1999). "External Economies at the Firm Level: Evidence from Swedish Manufacturing." Central Bank of Sweden Working Paper Series No. 89.

List, F. (1909). *The National System of Political Economy* (S.S. Lloyd, Trans.). London: Longmans, Green, and Company. (Original work published in 1841)

Liu, X., S. Schwaag Serger, U. Tagscherer, and A.Y. Chang. (2017). "Beyond Catch-Up—Can a New Innovation Policy Help China Overcome the Middle Income Trap?" *Science and Public Policy* 44(5): 656–669.

Loon, M. and R. Chik. (2018). "Efficiency-centered, Innovation-Enabling Business Models of High Tech SMEs: Evidence from Hong Kong." *Asia Pacific Journal of Management*: 1-25.

Lundvall, B.-A., K.J. Joseph, C. Chaminade, and J. Vang. (2002). *Handbook of Innovation Systems and Developing Countries Building Domestic Capabilities in a Global Setting*. Chelthenham, UK: Edward Elgar.

Lundvall, B-A, B. Johnson, E.S. Andersen, and B. Dalum. (2009). "National Systems of Production, Innovation and Competence Building." *Research Policy* 31: 213–231.

Lundvall, B. (1988). "Innovation as an Interactive Process: From User–Producer Interaction to the National System Of Innovation," in G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (Eds), *Technical Change and Economic Theory*. London: Frances Pinter.

Lundvall, B. (1992). *National Systems of Innovation: An Analytical Framework*. Pinter Publishing.

Mahmood, I.P. and W. Mitchell. (2004). “Two Faces: Effects of Business Groups on Innovation in Emerging Economies.” *Management Science* 50(10): 1348-1365.

Malerba, F. (2002). “Sectoral Systems of Innovation and Production.” *Research Policy* 31: 247–264.

Malerba, F. (2004). *Sectoral Systems of Innovation: Concepts, Issues and Analyses of Six Major Sectors in Europe*. Cambridge University Press.

Malerba, F. and R. Nelson. (2011). “Learning and Catching Up in Different Sectoral Systems: Evidence from Six Industries.” *Industrial and Corporate Change* 20(6): 1645–1675.

Malerba, F. and R. Nelson. (2012). *Economic Development as a Learning Process: Variation Across Sectoral Systems*. Chelthenham, UK: Edward Edgar.

Malerba, F. and S. Mani. (eds.) (2009). *Sectoral Systems of Innovation and Production in Developing Countries: Actors, Structure, and Evolution*.

Malerba, F., S. Mani, and P. Adams. (eds.) (2017). *The Rise to Market Leadership New Leading Firms from Emerging Countries*. Cheltenham, UK: Edward Elgar Publishing, Inc.

Marengo, L. and A. Sterlacchini. (1990). “Intersectoral Technology Flows. Methodological Aspects and Empirical Applications.” *Metroeconomica*, 41, 19–39.

Mathews, J.A. (2002). “Competitive Advantages of the Latecomer Firm: A Resource-Based Account of Industrial Catch-Up Strategies.” *Asia Pacific Journal of Management* 19: 467–488.

Mathews, J.A. (2005). “The Intellectual Roots of Latecomer Industrial Development.” *International Journal of Technology and Globalisation*, 1(3/4).

McMillan, M.S. and D. Rodrik. (2014). “Globalization, Structural Change and Productivity Growth, with an Update on Africa.” *World Development* 63: 11-32.

Medda, C. and G. Piga (2014). "Technological Spillovers and Productivity in Italian Manufacturing Firms." *Journal of Productivity Analysis* 41: 419–43.

Merton RK. (1968). "The Matthew effect in science." *Science* 159:56–63

Merton RK. (1988). "The Matthew Effect in Science. II: Cumulative Advantage and the Symbolism of Intellectual Property." *Isis* 79(4):606–33.

Metcalfe, J.S. and L. Georghiou (1997). "Equilibrium and Evolutionary Foundations Of Technology Policy." In J.S. Metcalfe and U. Cantner (eds.) *Change, Transformation and Development.* Berlin: Springer-Verlag.

Metcalfe, J.S. (2005). "Systems Failure and the Case for Innovation Policy." In M. Matt, P. Llerena, A. Avadikyan (Eds.), *Innovation policy in a knowledge based economy: theories and practices*. Berlin: Springer Verlag.

Metcalfe, J.S. and L. Georghiou. (1997). "Equilibrium and Evolutionary Foundations of Technology Policy." *OECD STI Review*, 75-100.

Miao, Y., J. Song, K. Lee, and C. Jin. (2018). "Technological catch-up by east Asian firms: Trends, issues, and future research agenda." *Asia Pacific Journal of Management* 35: 639–669.

Mohnen, P. (1997). "Introduction: Input–Output Analysis of Interindustry R&D Spillovers." *Economic Systems Research* 9(1): 3–8.

Montresor, S. and G.V. Marzetti. (2008). "Innovation Clusters in Technological Systems: A Network Analysis of 15 OECD Countries for the Middle '90s." *Industry & Innovation* 15: 319–345.

Montresor, S. and G.V. Marzetti. (2009). "Applying Social Network Analysis to Input–Output Based Innovation Matrices: An Illustrative Application To Six OECD Technological Systems for the Middle 1990s." *Economic Systems Research* 21(2): 129-149.

Morrison, A. and R. Rabellotti. 2017. "Gradual Catch Up and Enduring Leadership in the Global Wine Industry." *Research Policy* 46(2): 417–430.

Muscat, R. J. (1994). *The Fifth Tiger*. Tokyo: United Nations University Press.

National Film Production Center (국립영화제작소). (1975). Jungsu Vocational Training Institute (정수직업훈련원). https://www.kdevelopedia.org/Resources/social-development/jungsu-vocational-training-institute-%EC%A0%95%EC%88%98%EC%A7%81%EC%97%85%ED%9B%88%EB%A0%A8%EC%9B%90--02201603080143659.do?fldIds=TP_SOC%7CTP_SOC_ED#.XOhyTogzbD5

Nelson, R. (2008). "Economic Development from the Perspective of Evolutionary Economic Theory." *Oxford Development Studies* 36(1): 9-21.

Nelson, R. and S. Winter. (1982). *An Evolutionary Theory of Economic Change.* Cambridge, MA: The Belknap Press of Harvard University.

Niosi, J. and S.E. Reid. (2007). "Biotechnology and Nanotechnology: Science-based Enabling Technologies as Windows of Opportunity for LDCs?" *World Development* 35(3): 426-438.

Nonaka, I. (1994). "A Dynamic Theory of Organizational Knowledge Creation." *Organization Science* 5(1): 14-37.

Nonaka, I. and J. Takeuchi. (1995). *The Knowledge Creating Company*. Oxford University Press.

Odagiri and Kinukawa (1997). "Contributions and Channels of Interindustry R&D Spillovers: An Estimation for Japanese High-tech Industries." *Economic Systems Research* 9(1): 127-142.

OECD. (2016). Science, Technology, and Patents Database. Accessed at http://www.oecd.org/.

Ohno, K. (2009). "The Middle Income Trap: Implications for Industrialization Strategies in East Asia and Africa." Discussion Paper. GRIPS Development Forum. Tokyo, Japan.

OICA (2018). Production Statistics. Accessed at http://www.oica.net/

Osterloh, M. and B.S. Frey. (2000). "Motivation, Knowledge Transfer, and Organizational Forms." *Organization Science* 11(5):538-550.

Parrilli, M.D. and H.A. Heras. (2016). “STI and DUI Innovation Modes: Scientific-Technological and Context-Specific Nuances.” *Research Policy* 45: 747–756.

Paus, E. (2017). “Escaping the Middle-Income Trap: Innovate or Perish.” ADBI Working Paper Series No. 685.

Paus, E., (2012). “Confronting the Middle Income Trap: Insights from Small Latecomers.” *Studies in Comparative International Development* 47(2): 115–138.

Pavitt, K. (1984). “Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory.” *Research Policy* 13: 343–373.

Penrose, E.T. (1959). *The Theory of the Growth of the Firm*. New York: John Wiley.

Perez, C., and L. Soete. (1988). “Catching-Up in Technology: Entry Barriers and Windows of Opportunity.” In Dosi, G., Freeman, C., Nelson, R., Silverberg, G., and L. Soete. (Eds.). *Technical Change and Economic Theory*. Pinter Publishers, London pp. 458–479.

Poetzsch, C. (2017). “Technology Transfer on a Two-Way Street: R&D Spillovers Through Intermediate Input Usage and Supply.” *Review of the World Economy* 153:735–751.

Pritchet, L. (1997). “Divergence, Big Time.” *Journal of Economic Perspective* 11(3): 3-17.

Pritchett, L. and L. Summers. (2014). “Asiaphoria Meets Regression to the Mean.” Working Paper 20573. NBER.

Quah, D. (1993). “Galton's Fallacy and Tests of the Convergence Hypothesis.” *Scandinavian Journal of Economics* 95(4): 427-443.

Radosevic, S. (1999). *International Technology Transfer and ‘Catch Up’ in Economic Development*. Chelthenham, UK: Edward Elgar.

Radosevic, S. and E. Yoruk. (2016). “Why Do We Need a Theory and Metrics of Technology Upgrading?” *Asian Journal of Technology Innovation*: 1-25.

Raj-Reichert, G. (2019). “Global Value Chains, Contract Manufacturers, and the Middle-Income Trap: The Electronics Industry in Malaysia.” *The Journal of Development Studies* (online): 1-19.

Ravenhill, J. (2001). “From National Champions to Global Partnerships: The Korean Auto Industry, Financial Crisis and Globalization.” MIT Japan Program Working Paper 01.04.

Rock, M.T. (1995). “Thai Industrial Policy: How Irrelevant Was It to Export Success?” *Journal of International Development*, 7(5), 745-757.

Diao, X., M. McMillan, and D. Rodrik. (2017). “The Recent Growth Boom In Developing Economies: A Structural-Change Perspective.” NBER Working Paper No. 23132.

Rodrik, D. (2004). “Industrial Policy for the Twenty-first Century.” Retrieved from http://myweb.rollins.edu/tlairson/pek/rodrikindpolicy.pdf

Rugman, A.M. and A. Verbeke. (2001). “Subsidiary-specific advantages in multinational enterprises.” *Strategic Management Journal* 22: 237–250.

Sato, H. (2009). “The Iron and Steel Industry in Asia: Development and Restructuring.” IDE Discussion Paper 210. Chiba, Japan: Institute of Developing Economies.

Scherer, F.M. (1982). “Inter-Industry Technology Flows and Productivity Growth.” *The Review of Economics and Statistics* 64(4): 627-634.

Shain, M.L. (1994). Thailand's Board of Investment: Towards a More Appropriate and Effective Rural Investment Promotion Policy. *Pacific Rim Law & Policy Journal*, 3(1).

Shin, J.-S. (2017). “Dynamic Catch-Up Strategy, Capability Expansion and Changing Windows of Opportunity in the Memory Industry.” *Research Policy* 46(2): 404-416.

Sims-Gallagher, K. (2006). *China Shifts Gears: Automakers, Oil. Policy and Development*. Cambridge, MA: MIT Press.

Siyanbola, W., A. Egbetokun, B.A. Adebowale, and O. Olamade. (2012). *Innovation Systems and Capabilities in Developing Regions: Concepts, issues and cases*. Surrey, UK: Gower.

Smith, K. (2000). “Innovation as a Systemic Phenomenon: Rethinking the Role of Policy.” *Enterprise and Innovation Management Studies* 1(1): 73-102.

Solow, R. (1957). “Technical Change and the Aggregate Production Function.” *The Review of Economics and Statistics* 39(3): 312-320.

Solow, R. (1962). “Technical Progress, Capital Formation and Economic Growth." *American Economic Review* 52(2): 76-86.

Spence, M. (2011). *The Next Convergence. The Future of Economic Growth in a Multispeed World*. New York: Farrar, Straus and Giroux.

STI Office of Thailand. (2017). R&D Survey.

Stiglitz, J. (1987). “Learning to Learn, Localized Learning and Technological Progress.” In P. Dasgupta and P. Stoneman (eds.). *Economic Policy and Technological Performance*. Cambridge University Press.

Stiglitz, J.E., J.Y. Lin, and C. Monga. (2013). “The Rejuvenation of Industrial Policy” World Bank Policy Research Working Paper No. 6628.

Techakanont, K. and T. Terdudomtham. (2004). “Evolution of Inter-firm Technology Transfer and Technological Capability Formation of Local Parts Firms in the Thai Automobile Industry.” *Journal of Technology Innovation* 12(2): 151-183.

Teece, D. and G. Pisano. (1997). “The Dynamic Capabilities of Firms: an Introduction.” *Industrial and Corporate Change* 3(3): 537-556.

Teece, D.J. (2009). *Dynamic Capabilities and Strategic Management: Organizing for Innovation and Growth*. Oxford: Oxford University Press.

Terleckyj, N.E. (1980). “Direct and Indirect Effects of Industrial Research and Development on the Productivity Growth of Industries.” in: J. W. Kendrick and B. N. Vaccara (Eds.) *New Development in Productivity Measurement and Analysis*. Chicago: University of Chicago Press.

Thailand Automotive Institute and Ministry of Industry. (2002). Master Plan of the Automotive Industry 2002-2006.

Thailand Automotive Institute and Ministry of Industry. (2007). Master Plan of the Automotive Industry 2017-2011.

Thailand Automotive Institute and Ministry of Industry. (2012). Master Plan of the Automotive Industry 2012-2016.

Thailand Board of Investment. (2007a). “BoI to Promote Eco-Cars Maximum Incentives for Integrated Car Assembly and Key Parts Manufacturing Projects.” Press Release.

Thailand Ministry of Commerce. (online). Motor Cars – Exports. MENUCOM. Retrieved on 1 November 2014 from http://www2.ops3.moc.go.th/.

Thun, E. (2006). *Changing lanes in China: Foreign direct investment, local governments, and auto sector development*. New York: Cambridge University Press.

Timmer, M.P. A.A. Erumban, B. Los, R. Stehrer, and G.J. de Vries. (2014). “Slicing Up Global Value Chains.” *The Journal of Economic Perspectives* 28(2): 99-118.

Tsai, C.H., D.S. Zhu, B.C.-T. Ho, and D.D. Wu. (2010). “The Effect of Reducing Risk and Improving Personal Motivation on the Adoption of Knowledge Repository System.” *Technological Forecasting & Social Change* 77: 840–856.

Tushman, M.L. and P. Anderson. (1986). “Technological Discontinuities and Organizational Environments.” *Administrative Science Quarterly* 31(3): 439-465.

UNCOMTRADE. (2019). International Trade Statistics Database. Accessed at https://comtrade.un.org/.

Urraca-Ruiz, A. (2019). “On the evolution of technological specialization patterns in emerging countries: comparing Asia and Latin America.” *Economics of Innovation and New Technology* 28(1): 100-117.

US Patent and Trademark Office. (online). Statistics. Retrieved on 1 December 2014 at http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utl.htm.

van Meijl, H. (1997). “Measuring Intersectoral Spillovers: French Evidence.” *Economic Systems Research* 9(1): 25-46.

van Meijl, H. (1997) Measuring Intersectoral Spillovers: French Evidence. *Economic Systems Research* 9” 25–46.

Verspagen.B. (1997). "Measuring Intersectoral Technology Spillovers: Estimates from the European and US Patent Office Databases." *Economic Systems Research* 9(1): 47-65

Vivarelli, M. (2014). "Structural Change and Innovation as Exit Strategies from the Middle Income Trap." IZA Discussion Paper 8148, Institute for the Study of Labor (IZA), Bonn, Germany.

Vivarelli, M. (2015). "The Middle Income Trap: A Way out Based on Technological and Structural Change." *Economic Change and Restructuring* 49(2): 159–193.

Vuori, S. (1997). "Interindustry Technology Flows and Productivity in Finnish Manufacturing." *Economic Systems Research* 9(1): 67-80.

Wailerdsak, N. and A. Suehiro. (2010). "Business Groups in Thailand." In A.M. Colpan, T. Hikino, and J.R. Lincoln (Eds.). *The Oxford Handbook of Business Groups*. Oxford University Press.

Wang, Y. (2016). "The Political Economy of the Middle-Income Trap: Implications for Potential Growth." *Asian Development Review* 33(2): 167–181.

Weber, K.M. and H. Rohracher. (2012). "Legitimizing Research, Technology and Innovation Policies for Transformative Change Combining Insights from Innovation Systems and Multi-Level Perspective in a Comprehensive 'Failures' Framework." *Research Policy* 41: 1037–1047.

Wells, P. and P. Nieuwenhuis. (2012). "Transition Failure: Understanding Continuity in the Automotive Industry." *Technological Forecasting and Social Change* 79(9): 1681-1692.

Winter, S. (1987). "Knowledge and Competence as Strategic Assets." In David Teece, (ed.), *The Competitive Challenge-Strategies for Industrial Innovation and Renewal*: 159-84. Cambridge, Mass.: Ballinger.

Wolff, E.N. (1997). "Spillovers, Linkages and Technical Change." *Economic Systems Research* 9(1): 9-23.

Wong, P. (1999). "National Innovation Systems for Rapid Technological Catch-up: An Analytical Framework and a Comparative Analysis of Korea, Taiwan and Singapore." Conference paper. Presented at

DRUID Summer Conference on National Innovation Systems, Industrial Dynamics and Innovation Policy, Rebild, Denmark.

Woo, W.T. (2009). “Getting Malaysia out of the Middle-Income Trap.” (August 3, 2009). Available at SSRN: https://ssrn.com/abstract=1534454 or http://dx.doi.org/10.2139/ssrn.1534454

Woolthius, R.K., M. Lankhuizen, and V. Gilsing. (2005). “A System Failure Framework for Innovation Policy Design.” *Technovation* 35: 609-619.

World Bank. (2013). *China 2030: Building a Modern, Harmonious, and Creative Society*. Washington, DC: World Bank.

World Intellectual Property Office. (online). World Intellectual Property Office Statistics Database. Updated June 2014. Retrieved on 7 December 2014 from http://ipstatsdb.wipo.org/ipstatv2/.

Wu, D.D., X. Kefan, L. Hua, Z. Shi, and D.L. Olson. (2010). “Modeling Technological Innovation Risks of an Entrepreneurial Team Using System Dynamics: An Agent-Based Perspective.” *Technological Forecasting & Social Change* 77: 857-869.

Xiao, Y., A. Tylecote, and J. Liu. (2013). “Why Not Greater Catch-Up by Chinese Firms? The Impact of IPR, Corporate Governance and Technology Intensity on Late-Comer Strategies.” *Research Policy* 42: 49–764.

Yao, Z. (2015). “How Can China Avoid the Middle Income Trap?” *China and World Economy* 23(5): 26-42.

Ye, L. and P.E. Robertson. (2016). “On the Existence of the Middle-Income Trap.” *Economic Record* 92(297): 173–189.

Yilmaz, G. (2016). "Labor Productivity in the Middle Income Trap and the Graduated Countries.” *Central Bank Review* 16: 73-83.

Yu, J., F. Malerba, P. Adams, and, Y. Zhang. (2017). “Related Yet Diverging Sectoral Systems: Telecommunications Equipment and Semiconductors in China.” *Industry and Innovation* 24(2): 190-212.

Yusuf, S. and K. Nabeshima. (2009). “Can Malaysia Escape the Middle-Income Trap: A Strategy for Penang.” Policy Research Working Paper No. 4971. World Bank.

Zahra, S.A. and G. George. (2002). "Absorptive Capacity: A Review, Reconceptualization, and Extension." *The Academy of Management Review* 27(2): 185-203.

Zhang, D. (2016). "The Mechanism of the Middle Income Trap and the Potential Factors Influencing China's Economic Growth." *Frontiers of Economics in China* 9(3): 499-528.

Appendix

Figure A-1: Embodied knowledge network densities of the auto industry over time in Korea

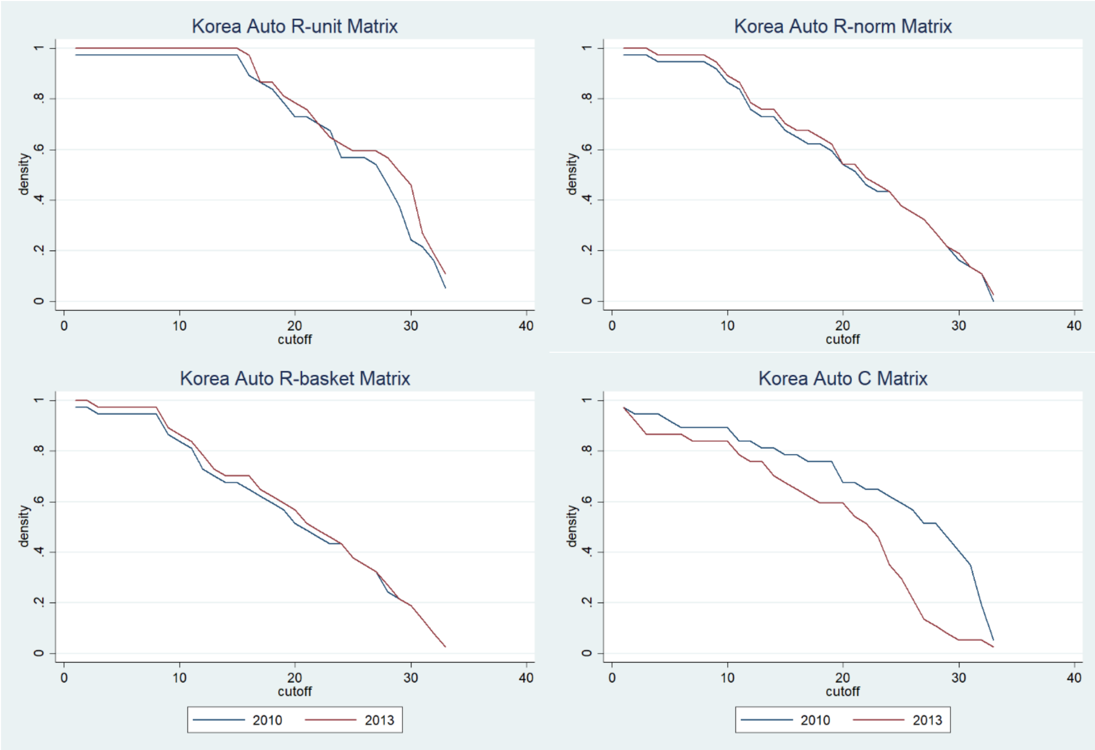


Figure A-2: Embodied knowledge network densities of the auto industry over time in Thailand

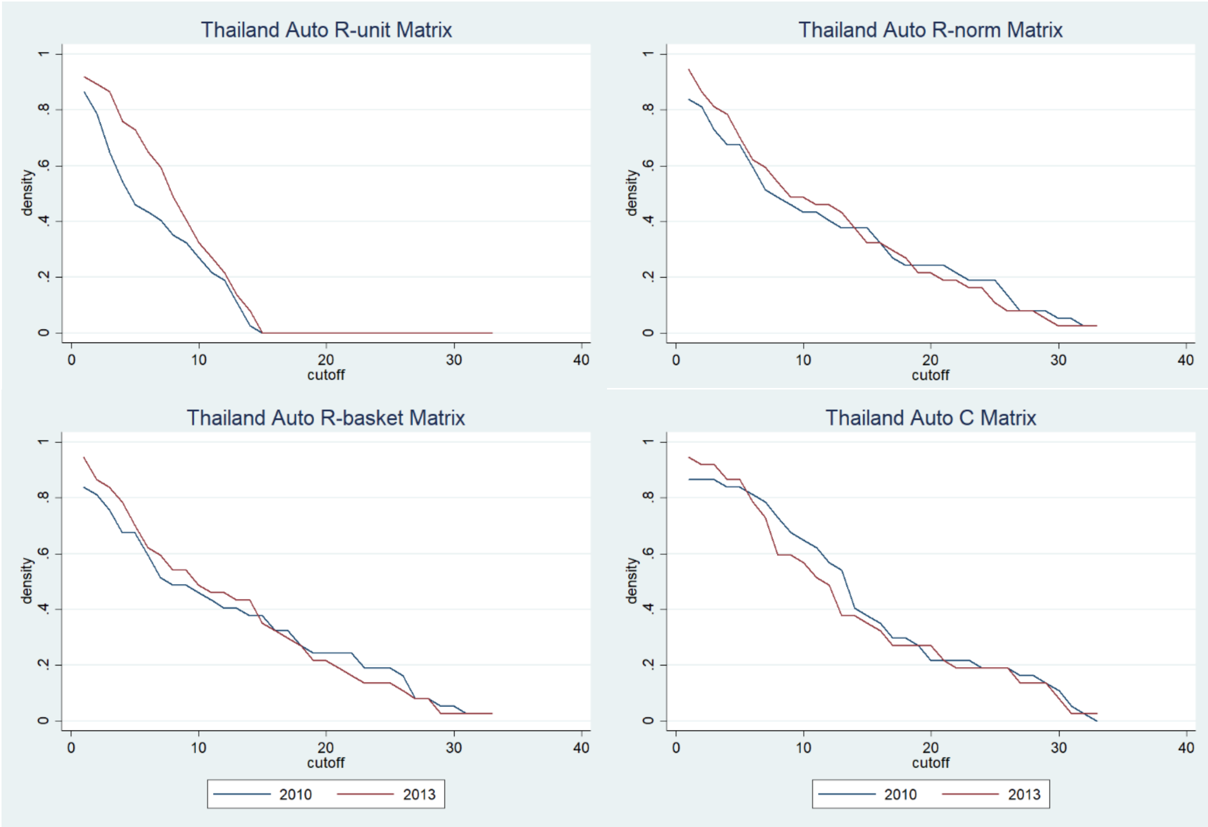


Figure A-3: Disembodied knowledge network densities of the auto industry in Korea and Thailand, 2010

Figure A-4: Disembodied knowledge network densities of the auto industry over time in Korea

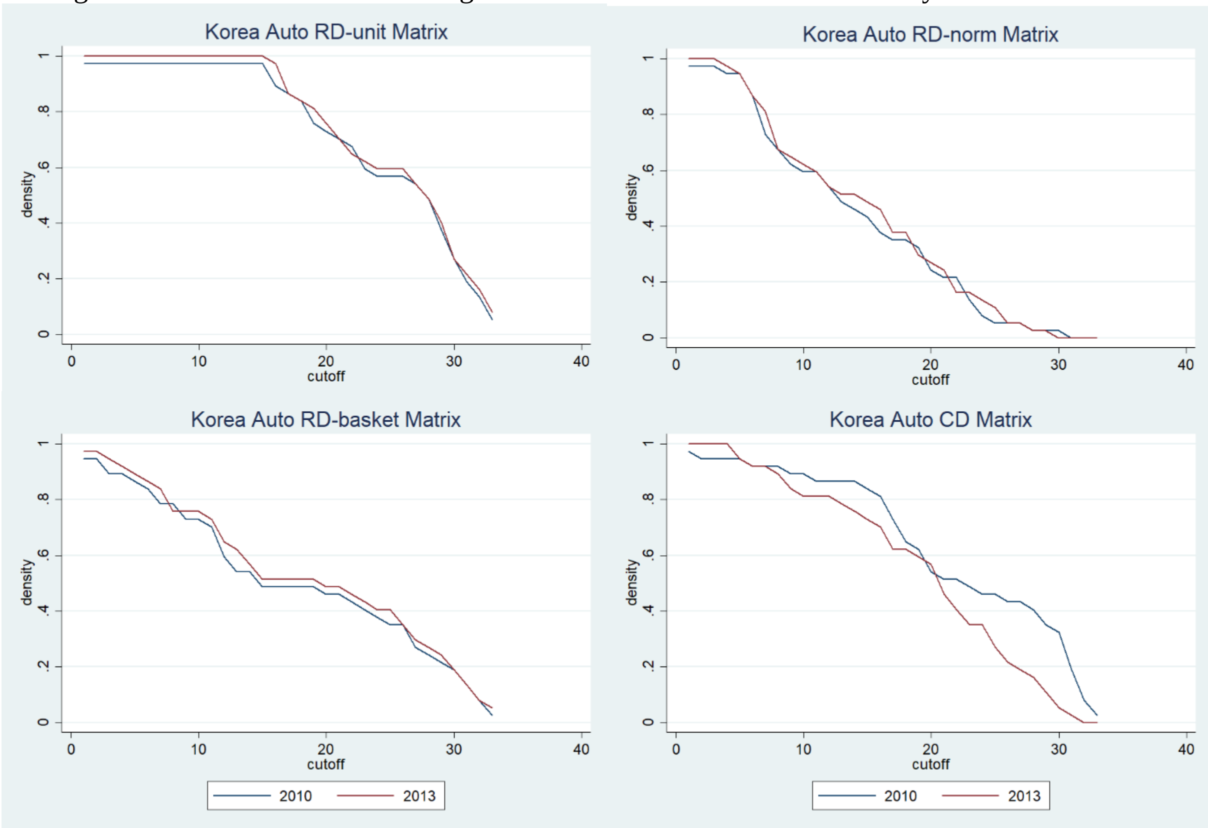


Figure A-5: Disembodied knowledge network densities of the auto industry over time in Thailand

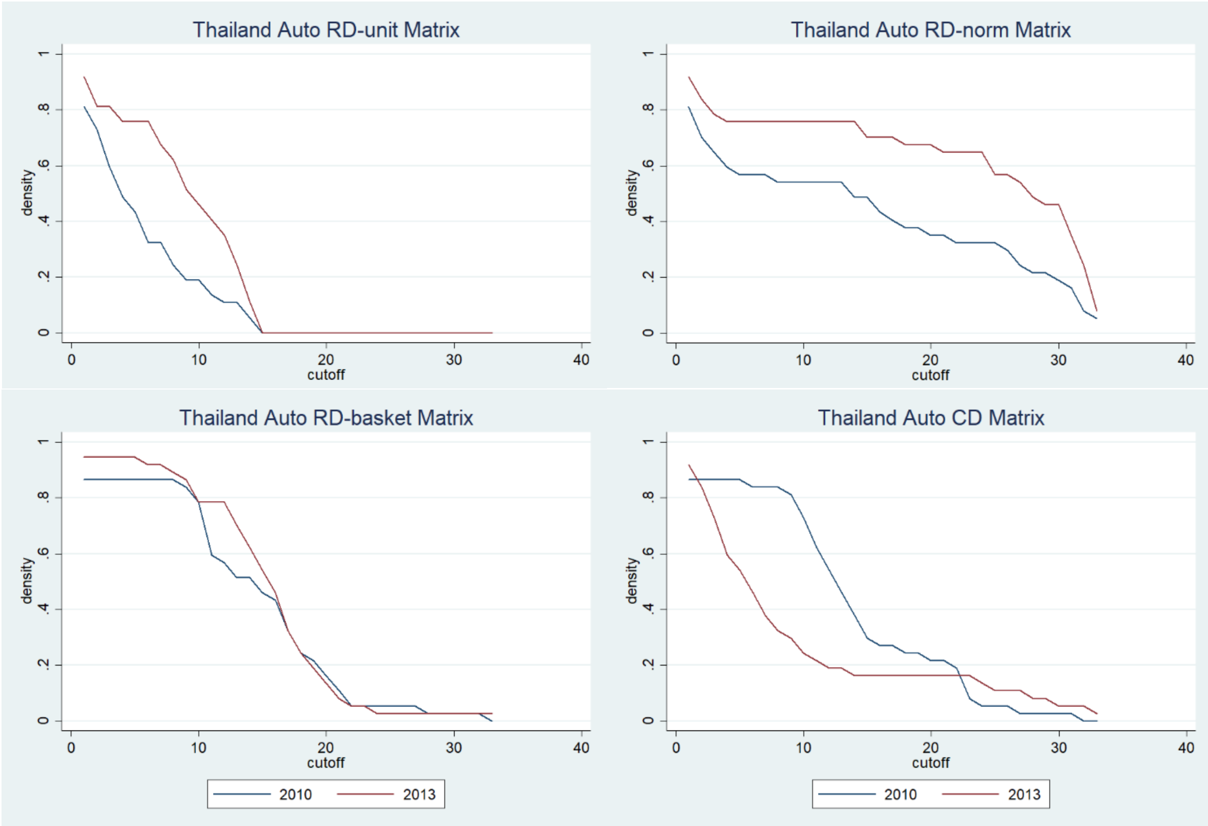


Figure A-6: Embodied in-degree centrality

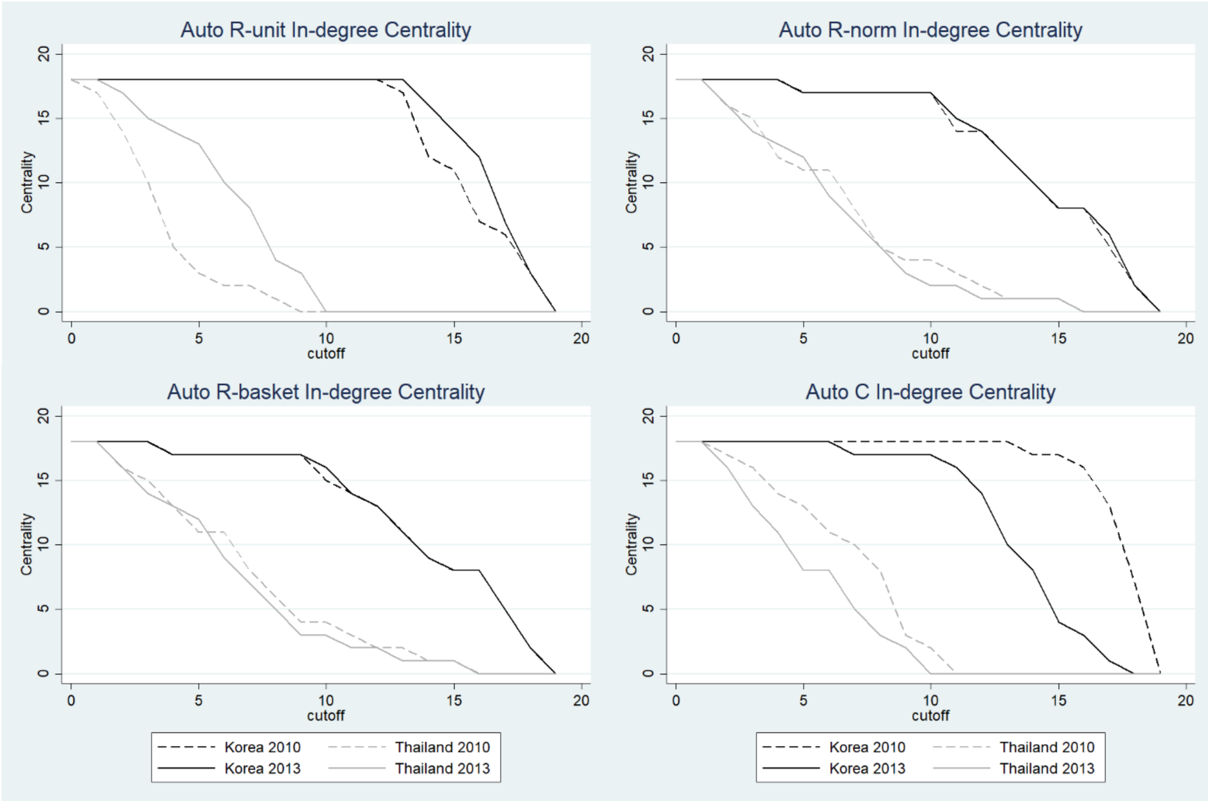


Figure A-7: Embodied out-degree centrality

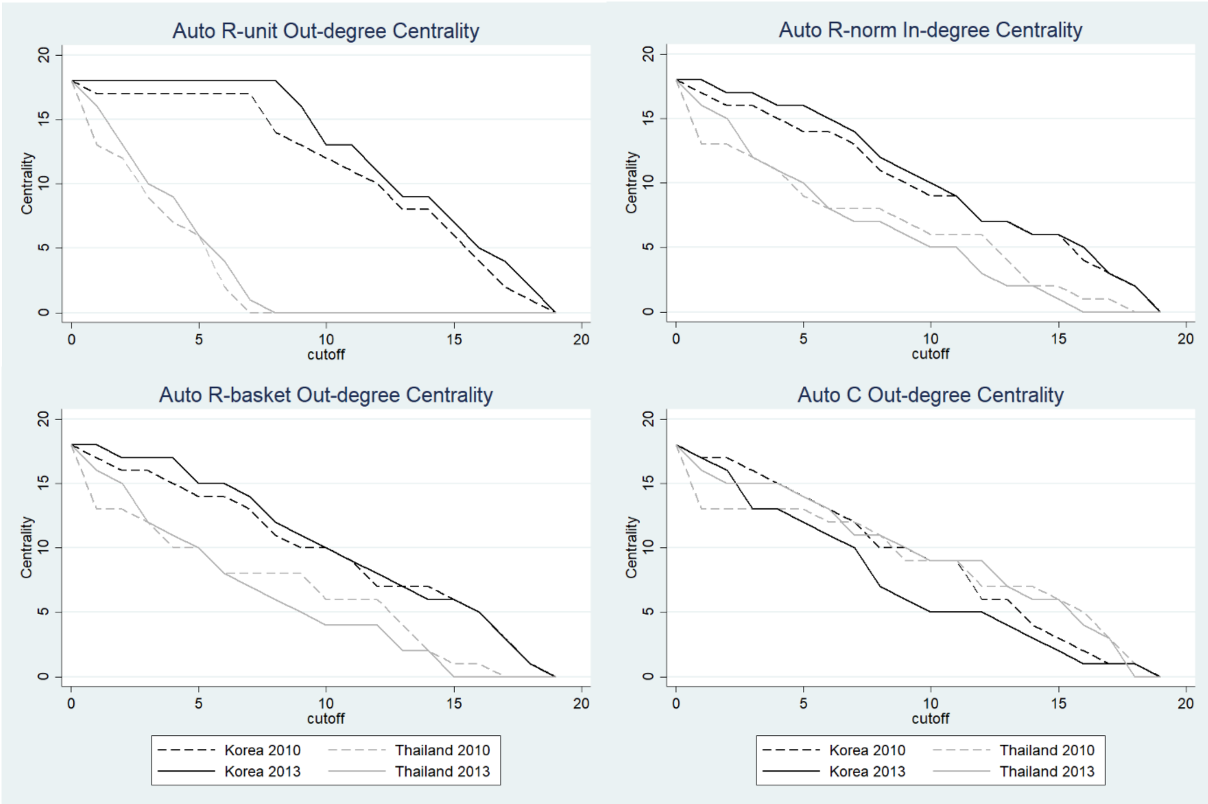


Figure A-8: Disembodied in-degree centrality

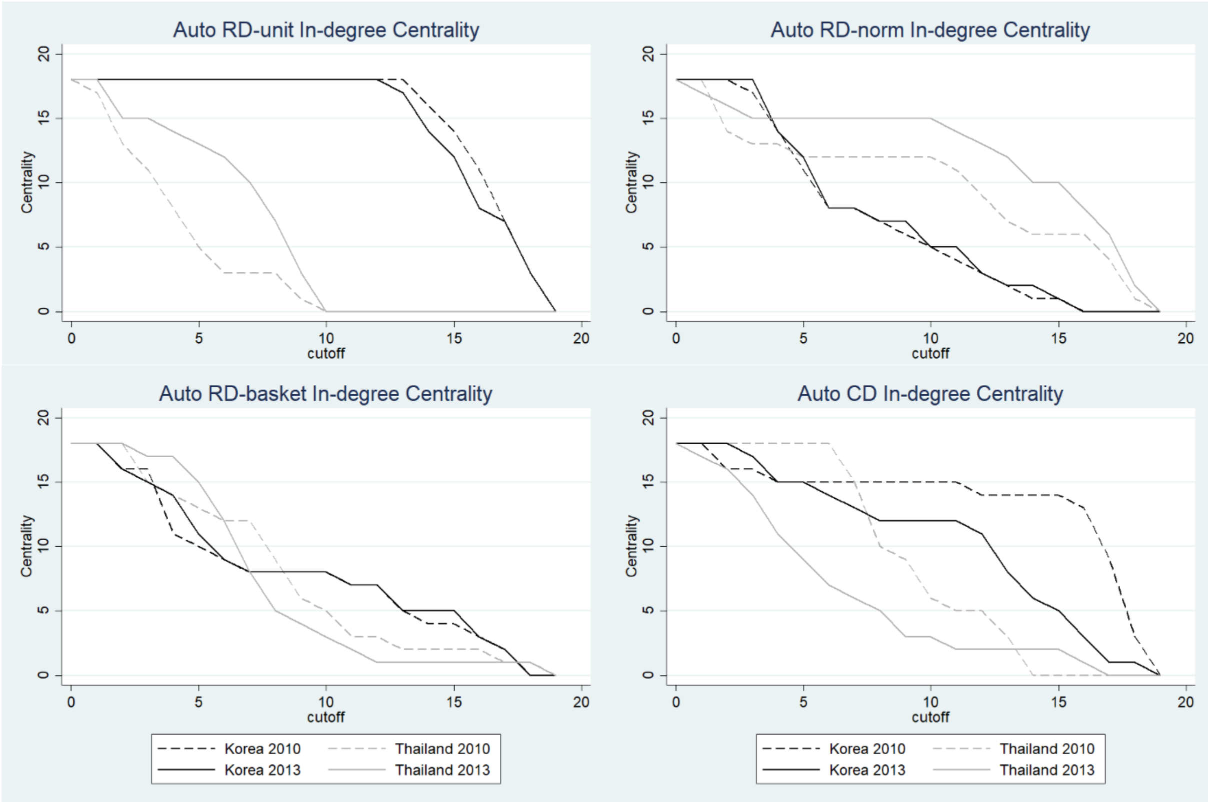
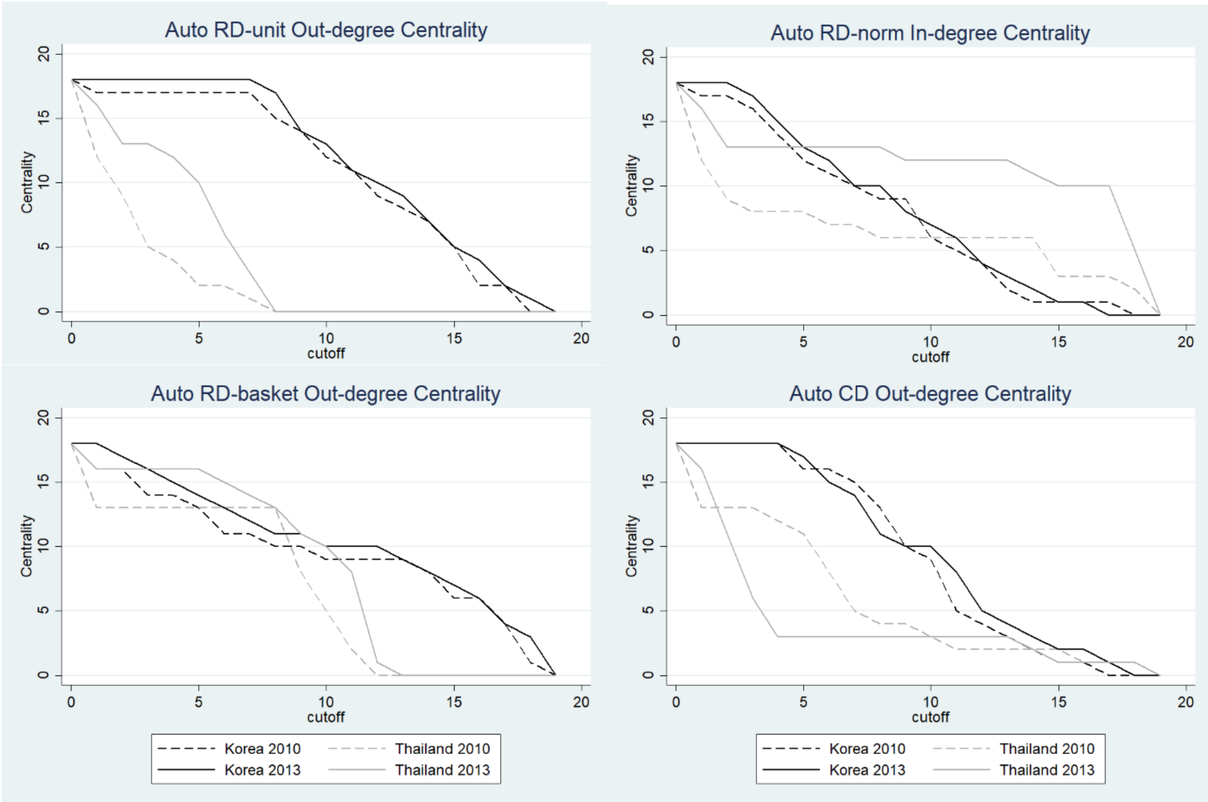


Figure A-9: Disembodied out-degree centrality



Abstract (Korean)

초 록

지식 원천의 내외부적 효과와 중간소득함정에 대한 시사점: 한국과 태국 간의 비교연구

Sira Maliphol
Technology Management, Economics, and Policy Program
The Graduate School
Seoul National University

중간소득함정은 국가 경제의 구조적 변화를 통한 경제 성장이 실패하면서 비롯된다. 구조적 변화는 생산과 혁신 능력을 통해서 실현될 수 있다. 구조적인 변화가 성장으로 이어질지의 여부는 성장 원동력의 혁신 기반 여부에 따른다. 본 논문은 한국과 태국의 능력 개발 패턴에 대한 비교 연구를 통해서 중간소득함정에서 전환하는 데의 차이를 보여준다.

국가혁신체제에 대한 연구는 보통 선진국에 초점을 맞추며 생산성 동력과 개발국의 경제적 성장을 간과한다. 소득에 있어 하위권에 속한

개발국의 입장에서는 다소 적은 수의 혁신 중심 경제로의 전환 사례와 접하게 된다. 이처럼 혁신 전환 실패에 대한 과거 연구가 없기 때문에 본 연구는 탐색적 조사에 해당한다. 본 연구에서 혁신 체제 전환의 가능한 요인 그리고 나아가 전환의 실패를 전적으로 다룬다. 지식의 축적이 곧 혁신을 몰기 때문에 다음 세 가지 세부 연구는 여러 종류의 지식네트워크를 통한 지식의 축적을 측정하고 여러 종류의 지식 축적의 결정 요인과 해당 기관을 알아본다.

제 2 장은 계량적 연구로서, 국가혁신체제로 성공적으로 전환한 대한민국과 전환에 실패한 태국의 서로 다른 두 형태의 경제체제에 있어 여러 가지 지식흐름의 영향을 살펴본다. 한국의 경우, 외국인 직접투자를 통한 국가 외부 생산 능력 원동력은 생산성 성장에 긍정적인 영향을 끼치지 않는다. 대신 한국의 산업은 연구개발 능력과 그와 관련된 파급 효과에 의존한 혁신 능력에서 추진력을 갖는다. 태국에서는 아직 생산 능력이 성장의 주요한 또한 유일하게 유의미한 원동력이다. 연구개발을 통한 학습의 효율성을 국가 경제 전반적으로 확산하여야 한다.

제 3 장은 한국과 태국의 자동차 산업을 양면적인 접근 방법으로 살펴본다. 첫째, 네트워크 분석을 통해 혁신 체제에 있어 지식네트워크의 두 주요 흐름인 체화된 그리고 비체화된 지식네트워크에 대한 단편을 제공한다. 체화 그리고 비체화 네트워크는 각 나라의 지식흐름의 상대적 힘을 보여준다. 한국의 지식네트워크가 더 강하며 기술 체제와 하부 체제에서 측정되었을 때 시간의 흐름에

따라 더욱 견고해졌다. 태국의 지식네트워크는 다소 애매한 결과를 보인다. 다시, 지식네트워크의 주요 성장은 연구개발과 무관한 활동에서 비롯된다.

제 3 장의 두 번째 부분에서는 변화의 역학을 이해하기 위해 산업 분야의 혁신 체제를 살펴본다. 체제 내의 산업들의 최고 수준인 행위자들이 양 국가에서 똑같이 상위권을 유지하고 대부분의 기업이 하위권에서 박탈한다. 하지만 글로벌한 관점에서 따라잡기의 차이는 매우 다르다. 현대자동차는 유일하게 생존하는 한국 자동차 기업이다. 현대자동차의 생존은 분야별 혁신 체제 내에서의 기관들이 육성한 혁신 능력에 크게 의존한다. 대조적으로, 태국 자동차 산업의 상위권 기업들은 모두 외국 혁신 능력을 통해 시장을 통합하고 있는 외국 다국적 기업들이다.

제 4 장은 국가적 관점으로 돌아간다. 국가적 혁신 체제의 관점에서 한국은 현대, 삼성이나 LG 와 같이 여러 산업에 있어 높은 혁신 능력을 갖춘 세계적인 경쟁력의 기업들을 개발할 수 있었다. 태국의 경우, 혁신 체제 전환의 실패는 태국의 중간소득함정의 근본적인 요인으로 이해된다. 제 3 장에서 살펴본 자동차 산업 분야와 비슷한 이유로, 다국적 기업이 가장 큰 분야인 제조업은 지배한다. 나라의 가장 큰 회사들이 경쟁하는 분야들은 경쟁으로부터 보호되어 혁신 능력의 발달에 반인센티브를 받는다. 국가 혁신 체제에서 약한 행위자(Intarakumnerd et al., 2002)는 많이 변하지 않았다. 본 연구는 지식의 축적에 영향을

끼치는 기관과 정책이 늦게 형성되었고 본 기관과 정책이 오히려 축적의 과정을 늦추었다는 것을 발견한다.

본 연구의 시사점은 혁신 능력을 모는 여러 가지 지식을 강조한다. 지식의 종류에 따른 생산성 성장 요인의 차이는 혁신 전환, 그러므로 성장의 중요한 부분이다. 능력이 다양화되면서도, 이 다양성의 일부에는 새로운 능력들이 이미 존재하는 능력들에 첨부되어 관리 복합성을 증가시켜야 한다. 나아가 국가의 정책의 여러 경로를 통하여 지식 파급 효과에 이바지하는 혁신 능력의 “인위적” 수요를 장려할 수 있다. 연구개발 지출은 이미 계획에 따르기 때문에 정책의 초점을 여러 종류의 지식에 따라 더욱 효율적이고 급속하게 지식 노동자의 혁신 효과를 증가하기 위한 방안을 모색하는 데에 맞추어야 한다.

주요어: 혁신 체제; 혁신 전환 실패; 지식의 종류

학 번: 2013-31308