Capability Failure and Industrial Policy to Move beyond the Middle-Income Trap: From Trade-based to Technology-based Specialization

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Abstract

This paper compares market, system, and capability failures as a justification for industrial policy, to argue that capability failure is most serious and unique in developing countries. It identifies failure of technological capability as the source of the middle-income trap. For a developing country to go beyond the middle-income stage, this paper suggests the implementation of technological specialization in a shorter cycle technology sectors where new technologies emerge frequently and existing ones become obsolete quickly, and the latecomers thus do not have to master existing technologies dominated by the incumbent. This paper suggests a three-stage based implementation strategy to build technological capabilities. The first stage involves the assimilation of foreign technology (operational skills and production technology) and know-how through licensing, FDI, or technology transfer from public research agencies, and the second stage involves learning via co-development contracts and public-private consortia once the latecomer firms establish their own in-house R&D labs as a physical bases for more indigenous learning. The final stage of learning is leapfrogging to emerging technologies which involve public-private R&D consortia and/or exclusive standard policy, procurement, and user subsidies for initial market provision.

Key words: technology policy, industrial policy, specialization, middle income trap, capability failure, leapfrogging, market failure

1. Introduction

The disappointing economic performance of the past two decades under the Washington Consensus of the 1980s and 1990s and the impact of the 2008 global financial crisis have resulted in the revival of industrial policy as a keyword in development literature. New literature in the same vein include the works of Cimoli, Dosi and Stiglitz (2009), as well as those of Lin (2012), Lee and Mathews (2010), and Wade (2012). Industrial policy is a broad concept. According to Johnson (1982), it refers to policies that improve the structure of a domestic industry in order to enhance a country's international competitiveness. Variants of industrial policies existed in successful countries, such as the UK from the 14th to the 18th centuries, the US and Germany in the 19th century, Japan in the late 19th century, and Korea and Taiwan in the late 20th century (Cimoli et al., 2009).

Empirical studies report conflicting results on the effectiveness of industrial policy. Although there are qualitative evidence indicating that industrial policy has been used in East Asian economies, which have grown rapidly as they changed their industrial structures (Johnson, 1982; Amsden, 1989; Wade, 1990), the impact of industrial policy has often been unverified quantitatively. According to Beason and Weinstein (1996), tariff protection, preferential tax rates, and subsidies did not affect the rate of capital accumulation or TFP in Japan from 1955 to 1980. Moreover, nominal tariff was negative and significant to the growth rate of labor productivity and total factor productivity (TFP) at the sectoral level in Korean industries from 1963 to 1983 (Lee, 1996). Nevertheless, several studies verify the positive contribution of industrial policy. Shin and Lee (2012), using the same period and sectoral data as Lee (2006), find that tariff protection, especially when combined with export market discipline, leads to the growth of export share and RCA. They also argue that the goal of industrial policy was not productivity at the early stage – as in the 1970s – but output or market share growth. Aghion, Dewatripont, Du, Harrison, and Legros (2011) also find that subsidies widely distributed among Chinese firms have had a positive impact on both TFP and the innovation of new products in the sectors with a high level of competition. Both of these recent studies identify competition or discipline as a common precondition for effective industrial policy.

One way to interpret this diverse outcome is that it might be difficult to verify the average positive impact of industrial policy because the effects tend to appear only in certain conditions, depending upon specific contexts (countries or sectors). Moreover, these studies indicate the significance of the criteria used in assessing the effectiveness of industrial policy. For example, productivity has become an important criterion only since the late 1980s, that is, after the Korean government shifted its policy tools from tariffs to research and development (R&D) subsidies as well as joint R&D; actually, enhanced innovation capabilities led to Korean firms' productivity catch-up with Japanese firms from 1985 to 2005 (Jung & Lee, 2010). Given that structural change in an economy is a long-term process, the idea of adopting different policy tools over time is consistent with the reasoning that industrial policy should deal with the various dimensions of capabilities of firms and industries in the latecomer countries. In other words, different tools are necessary depending on whether the target involves simple operational or production capabilities, investment capabilities, or technological capabilities at the advanced level.

The current paper suggests a capability-based view of industrial policies and recommends specific implementation strategies to build specific capabilities at various stages of economic development. For a developing country, it is critical to enhance its capability to produce and sell products in the international market so that the country may earn foreign currency that it can then use to pay for imports of investment goods. However, the challenging part of this process is increasing that capability. Thus, capability building is the focus of a World Bank study compiled by Chandra (2006). A World Bank (2005) assessment of the reform decade of the 1990s also states that growth entails more than the efficient use of resources, and that growth-oriented action may be needed, for example, on technological catch-up or the encouragement of risk-taking for faster accumulation. According to studies on reform in Latin America by ECLAC, macroeconomic stability is not a sufficient condition for long-term growth, which is more closely tied to the dynamics of the production structure (Ocampo 2005). Lee and Mathews (2010) synthesize capability-based view as the Beijing-Seoul-Tokyo (BeST) consensus, which is commensurate with their firm-level study (Lee and Mathews, 2012) and country-level study of Korea (Lee, 2012b).

The capability-based view of development can be compared with the institution-focused view. The recent literature on economic development has argued on the relative importance of institutions, policies, and geography as determinants of growth. Although more works have been reported in favor of the first factor, i.e., institutions (e.g., Acemoglu, Johnson, & Robinson 2001, 2002; Rodrik et al. 2004), there is also criticism against its relevance, and certain scholars propose that human capital is a more robust determinant (Glaeser et al., 2004). Although institutions are, undoubtedly, a fundamental factor in long-term economic growth, they also have to be formed over the long run by specific policies. Specific policy ideas often precede the legislation embodying the goals. Ocampo

(2005) argues that a well-functioning broader institutional context is essential; however, it generally does not play a direct role in bringing about changes in the momentum of growth, and that the latter is more closely related to the dynamics of the production structure. In an econometric study using country panel analysis, Lee and Kim (2009) reveal that institutions and secondary education are significantly related to growth, but only in lower- and lower-middle income countries. According to their study, technological development and higher education are the significant growth factors, because the high levels of institutional development are similar in the case of upper-middle and high-income countries. This implies that middle-income countries aiming to reach high-income status should start emphasizing their technological capabilities.

This line of thinking brings the issue of technological capabilities into the debate on the middle-income trap. This concept is defined as a situation wherein middle-income countries struggle to remain competitive as low-cost, high-volume production ultimately hinders their transition to high-income status (World Bank, 2010; Yusuf & Nabeshima, 2009). This condition is relevant considering that numerous developing countries have achieved growth for a certain period (usually less than a decade) but are unable to sustain such growth over a longer period (Jones & Olken, 2005; Hausmann et al., 2005). Rodrik (2006) also cites the greater importance of sustaining growth than initiating it. We find more instances in Latin American countries, such as Brazil and Argentina, where growth was more or less stalled during the 1980s and the 1990s (Lee & Kim, 2009, Table 1; Paus~~e~~, 2011). By contrast, several countries moved beyond middle-income status to join the rich-country club. Examples of these are Korea and Taiwan, whose per capita incomes increased three-fold from the 1980s to the 1990s, from original levels similar to those of Latin American countries in the early 1980s. Although a significant volume of the literature on the poverty trap is relevant to low income countries, there are few empirical studies on how to sustain growth beyond the middle income level. Even the recent World Bank-sponsored growth commission report and a book by the leader of the commission (Spence, 2011) do not deal with the issue of sustaining growth in developing countries by targeting industries with comparative advantages. However, this issue is gaining increasing attention in a number of recent studies, such as those by Griffith (2011), Ohno (2010), Eichengreen et al. (2011), and Pause (2011).

One might ask why growth beyond the middle-income status is important, or is more important than spurring growth in low-income countries. One answer is that only when some middle-income countries move beyond the stage of producing and exporting low-cost, labor-intensive goods, can low-income countries achieve growth and sustain it, thereby attenuating the adding-up problem (Lee, 2013a). The adding-up problem occurs when all the developing countries flood the market with the same goods that they produce well, resulting in a decrease in the relative prices of these goods and less profits for the concerned sectors (Spence, 2011). From this perspective, it is crucial for China to move beyond its current specialization in low-cost, labor-intensive goods and shift toward manufacturing higher-end ones so that other latecomer countries can avoid the continuing competition with Chinese goods.

Thus, the current paper focuses on industrial policy for middle-income countries. Echoing the argument of Lee (2013a), we argue that the goal of industrial policy for middle-income countries is to promote technology-based specialization, as opposed to traditional trade-based specialization that may be more relevant to low-income countries. The new structural economics of Justin Lin also points out the need for dynamic comparative advantage, suggesting that the latecomers should target the industries with latent comparative advantage or mature industries from the countries that are slightly ahead of them. Although this is a sound practical guideline, a more theoretically grounded criterion is needed. As a more specific, differentiating criterion for targeting technology, this paper suggests a cycle time for technologies based on empirical evidence at the country, sector, and firm levels earlier proposed by Lee (2013a). The proposed guideline is also based on the fact that the successful catching-up countries, such as Korea and Taiwan, have specialized in short-cycle technology-based sectors. This strategy makes sense because in sectors with shorter technology cycle times, existing technologies become obsolete rapidly, and new technologies tend to emerge frequently (i.e., more opportunities emerge). Thus, the latecomers do not have to master existing technologies dominated by the incumbent.

In Section 2, the paper introduces the notion of capability failure, compared with the market and system failures that have also been used as a justification for state activism. We argue that the capability failure is more unique and serious in the context of developing countries, and that industrial policy should aim to cultivate the capabilities of the actors (private firms) in developing countries. Section 3 discusses the idea that the tools of industrial policy should be different and must change depending upon the stage of development, if not by country; it also presents the technology policy criteria for the middle-income countries, focusing on the cycle time of technologies. By presenting certain examples, Section 4 elaborates on the process of raising the technological capabilities of the firms along the three stages of development and learning. The capability building of the latecomer firms is explained along the three stages of learning: from the license/FDI-based learning, to the learning from contract/joint R&D with an external agent as the teacher/leader, and to the learning from the public-private R&D consortium with the latecomer firm as the main actor. Section 5 concludes the paper.

2. Market Failure, System Failure, and Capability Failure

A classical argument for government activism, particularly industrial policy, has been made in the context of market failure. The new structural economics of Lin (2012) as well as the initiatives put forward by Cimoli, Dosi, and Stiglitz (2009) argue for the pro-active role of the government. Governments are advised to promote infant industries as well as facilitate industrial upgrade and diversification, which are justified by identifying issues of information and coordination failure, as well as external conditions that can be regarded as instances of broadly defined market failure. Knowledge is rightly considered as the least mobile endowment of a country; thus, it is an optimal target area for industrial policy, which is defined as closing the knowledge gap (Greenwald and Stiglitz, 2012). The source of market failure is the fact that knowledge is a public good. Industrial policy is justified due to possible underinvestment in learning when there are flaws in the capital and risk markets, as well as market failure associated with imperfectly competitive industries and a spillover in learning. From this perspective, the actual amount of R&D is often less than the optimal amount that would prevail without market failure. Therefore, government subsidies to support R&D are suggested given the externality involved in the production of knowledge.

Another view that supports a proactive government is the system failure view based on neo-Schumpeterian economics, specifically the concept of the national innovation system of Nelson (1993), and Lundvall (1992). It calls for government activism with a different basis from that of the market failure view. One of its earliest proponents is Metcalfe (2005), whose work suggests the rationale for innovation policy in advanced economies. He argues that the process of innovation depends on the emergence and success of innovation systems connecting the various actors (components) engaged in the process. Then, the need for government activism arises, because effective interaction among the actors in the innovation systems does not exist naturally but has to be constructed, instituted for a purpose. In particular, some scholars (i.e., Bergek et al., 2008; Dodgson et al., 2011) observe that system failure often exists where missing or weak connections (and synergies) among actors tend to lead the system to lower performance. Innovation systems consist of firms, universities, public research laboratories, and government and financial institutions. The problems arise due to cognitive distance (Nooteboom, 2009) among these actors and/or tacitness of knowledge, which results in cognition failure. In this situation, the main function of the government is not to promote individual innovation events but to set the framework conditions in which innovation systems can better self-organize across a range of economic activities.

There is a need to re-assess the aforementioned views whether they can be considered as an effective rationale for the degrees and forms of government activism in developing countries, and applicable to their context. For instance, their common and hidden presumption is that the firms and other economic actors are already capable of production and innovation, and that the government must simply try to modify the extent of their activities or promote interaction among them. Let me dwell upon this point.

In the innovation system literature, the system is defined by the components in the boundaries and their interactions. The main focus is on the interaction among the actors, although the availability of knowledgeable or capable actors is also addressed.[1] However, the stark reality in developing countries is that the actors, especially the firms, have extremely weak levels of capability. This is a serious problem because, in the system failure view, the firms are regarded as the leaders in defining the system itself.

Typical market-failure-based justifications of R&D subsidy indicate the positive externality of R&D and its resulting undersupply. In the market failure view, the firms are assumed to be capable of conducting R&D, and their only problem lies in their inability to produce the optimal amount. The reasons for such situation are sought outside the firm, such as in the capital market or risk market, and these are the areas where the government's corrective action is suggested.

However, the reality in a number of developing countries is that private firms are unable to pursue and conduct in-house R&D, which they consider as an uncertain endeavor with uncertain returns. Thus, the problem is not less or more R&D but 'zero' R&D. Figure 1 illustrates the flat R&D-to-GDP ratio among the middle-income countries, which does not rise proportionally with per capita income. This is a serious condition because middle-income countries are the ones that should start

[1] For instance, Metcalfe notes that systems are not only defined in terms of their components, and the availabil ity of knowledgeable actors is a necessary but not a sufficient condition for the emergence of an innovation sy stem.

paying more attention to innovation efforts. This information clearly suggests that this is the root of the middle-income trap. Actually, using country-panel analysis, Lee and Kim (2009) verify that in transitioning from a middle- to high-income status, one of the constraints faced by countries is R&D effort or innovation capabilities. Thus, weak R&D effort is a critical matter that brings up the various capabilities of firms. In fact, the basic rationale for the market or system failure view is equally valid in the context of both advanced and developing countries. Therefore theory should be developed further to reflect the specificities of developing countries.

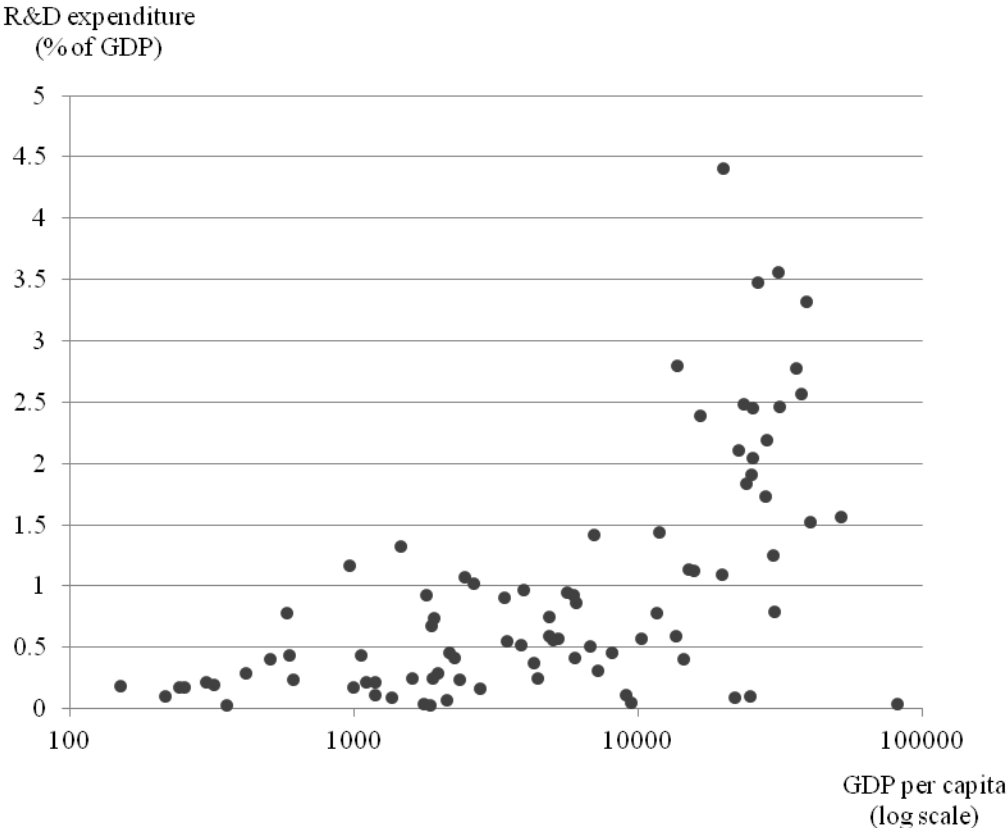

Figure 1. R&D-to-GDP Ratio of Countries in Different Income Groups

Note: Drawn by the author using the data from the UNESCO (R&D figures) and World Bank (WDI)

In contrast to the typical argument for government activism based on market failure or system failure, this paper emphasizes "capability failure" as a justification for government activism, and suggests specific ways to raise the capabilities of firms in developing countries. In developing countries where firms have a low R&D capability, a safer way of doing business is to buy or borrow external technologies or production facilities, as well as to specialize in less technical methods or assembly manufacturing. To move beyond such states, effective forms of government activism had better include not the simple provision of R&D funds but various ways to cultivate R&D capability itself. An innovation survey on Thailand conducted by Chaminade et al. (2012) identifies one related problem, i.e., the tendency of government policy to be limited only to tax incentives without implementing explicit measures to encourage Thai firms to take on greater risk in innovation. More effective and alternative forms of intervention may include the transfer of R&D outcomes performed by public research institutes and a public-private R&D consortium, which gained success in Korea and Taiwan.[2]

Such direct intervention is important because learning failure happens not only due to the fact that knowledge is a public good but also the fact that there has been no opportunity for effective learning due to historically-inherited conditions or policy failure. Seen from this angle, industrial policy is not about choosing winners but about choosing good students and matching them with good teachers or bringing them to good schools. Good schools may be in the form of licensing-based learning (of tacit knowledge) or public-private joint R&D projects, in which direct and cooperative learning take place. By contrast, banks that merely supply R&D money might not serve as good schools. Continuing with this analogy, the market failure view can be expressed as, "I will pay for your school so that you may take more classes," whereas the system failure may be expressed as, "Go to school and make more friends." However, both views do not pay enough attention to such factors as the initial aptitude of students, what is taught to them in schools, who the teachers are, and how they teach their students. In the capability view, these aspects are crucial to a successful industrial policy. Thus, the capability failure view essentially believes in the importance of raising the level of capabilities of the firms (students) and the various learning methods to be provided over the dynamic course of learning, not only in the elementary schools but also in the secondary and tertiary institutions. In sum, we need both tuition fees (R&D money) and good friends (linkages to other components in the system) in

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[2] For details, see Mathews (2002), Lee and Lim (2001), Lee et al. (2005), and OECD (1996).

schools, but the critical factors are the student himself, a good curriculum, a knowledgeable teacher, and an effective teaching method. Table 1 summarizes the aforementioned arguments.

Table 1. The Three Types of Failure (source: author)

	Market failure	System failure	Capability failure
Focus	Market institutions	Interaction among actors	Actors (firms)
Source	Knowledge as public good	Cognition failure from tacitness of knowledge	historically given; No learning opportunity
Example problem	Sub-optimal R&D	Lower R&D effects	No R&D
Solutions	R&D subsidies	Reducing cognitive distance	Access to knowledge and help in learning
School Analogy	Tuition support	Making more friends	Targeting student learning
Relevance	Developing and advanced countries	Developing and advanced countries	More unique to developing countries

Source: the author

3. From Industrial Policy to Technology Policy: From Low- to Middle-Income Countries

1) The Need for a Dynamic Shift of Policy Tools

Although economic development is a lengthy dynamic process that hinges on the specificities of the countries concerned, literature has not paid sufficient attention to the simple requirement of having corresponding policy tools for countries at different stages of development. An example is the recent debate on the relative importance of policies, institutions, and geography. Most of the studies on this subject search for one universal determinant of economic growth regardless of the stage of development. The opposite extreme is the argument presented by Rodrik and other scholars who emphasize the importance of identifying the binding constraints for each country (Rodrik 2006; Hausmann et al., 2008).

An ideal compromise may come in the form of stage- or group-specific factors for economic growth that are neither universal nor country-specific. This last view is consistent with Lin’s (2012) concept of new structural economics, which states that development policy should consider structural differences between developed and developing countries. One similar study is that of Lee and Kim (2009), which finds that technological development and higher education are more effective in generating growth for upper middle- and high-income countries, whereas secondary education and political institutions seem important for lower-income countries.

If we extend this logic to industrial policy, we realize that the tools of such policy should also depend on the stage of development, if not on the country itself. The traditional industrial policy tools come in the form of infant industry protection by tariffs or undervaluation of local currencies. However, if we consider industrial development as a long-term process that takes over 10 or 20 years, it is natural for the tools of policy to change over the course of economic growth. Such a dynamic view of industrial policy is warranted, because the capability level of the beneficiaries of such intervention would change over time as well.

Let us consider the example of industrial policy in Korea. Shin and Lee (2012) report that tariffs and other forms of protection led to export and output expansion through fixed investment during the early period (i.e., 1970s and 1980s), whereas Jung and Lee (2010) find that for a later period (i.e., from the mid-1980s to 2005), R&D investment stimulated by tax exemptions led to productivity growth. These two studies find that for both periods, the disciplinary impact of export orientation is significant, because it pushed the rents associated with tariffs (earlier period) and with an oligopolistic market structure (late period) used for fixed (earlier period) and R&D investments (later period), respectively. This finding suggests that the form of government activism in Korea has evolved from traditional industrial policy (i.e., trade policy) to technology policy (R&D policy).

Such a dynamic shift in policy tools is not simply imposed by the government but also reflects the available and/or desired level of firm capabilities that have been changing over time. Although Korea has grown fast with exports of labor-intensive and low-end goods, this growth strategy already reached its peaks by the mid-1980s. Around that time, Korea saw an increase in its own wage rate, which coincided with the emergence of lower-wage countries that competed against it in the world market. Given Korean firms' realization of the need to upgrade to higher-end or value-added goods, they began, for the first time, to establish in-house R&D centers, after which the tools for industrial policy switched toward tax exemption on R&D (Lee, 2013b; Lee and Kim, 2010). Another new and important form of state activism comes in the form of a policy to target directly the learning process of firms by involving them in the public-private R&D consortium. One prime example is the local import-substituting development of telephone switches (TDX) that occurred in the1980s (Lee, Mani, & Mu, 2012).

The Korean example indicates a dynamic shift in the form of government activism from the traditional industrial policy (tariffs and undervaluation) in the early stage of development, to technology policy (R&D subsidies and P-P R&D consortium) in the later stages. This dynamic shift is required for a developing country to evolve from a low-income to a middle-income status, and eventually move on up to a higher-income status. In the mid-1980s, Korea reached the level of a middle-income country with per capita GDP of approximately US$1,673 in nominal terms and US$3,223 in 2000 dollar terms (Lee & Kim, 2009: Table 1). It can be argued that without such a shift, any country may be stuck in the so-called middle-income trap, in which it struggles to remain competitive as a site for low-cost, high-volume production (World Bank, 2010; Yusuf and Nabeshima, 2009). One cause of the middle-income trap is the adding-up problem that occurs when all the developing countries flood the market with the similar goods that they tend to produce well (Spence, 2011).

Then, the connection between the two problems of the middle-income trap and adding-up becomes clearer. In other words, only when more successful middle-income countries advance from selling low-end goods to producing and selling higher-value-added or high-end goods can there be room for less successful or low-income countries to continue selling low-end goods and gain profit from it (Lee, 2013a). From this perspective, it is extremely important for China to move beyond its current specialization in low-cost labor-intensive goods to higher-ends goods. Such succession has happened in Asia, with the Korean and Taiwanese taking over the void left by the Japanese. Subsequently, as Korea and Taiwan moved further ahead, the next-tier countries occupied the positions they left.

Table 2 summarizes the preceding discussion. Different tools of industrial policy are suggested for lower- and middle-income countries. For the former, traditional tools such as tariffs, undervaluation of currencies, and entry control into sectors are suggested; for the latter, technology policy tools, such as R&D subsidies, public-private R&D cooperation and standard policies, are recommended. Corresponding to these tools, the channels of access to foreign or external knowledge from the perspective of local firms are listed herein (Lee 2005). Lower-income groups learn from FDI, OEM/assembly arrangement and licensing, whereas middle-income groups benefit from collaboration with public research labs and universities, overseas R&D outposts, international mergers and acquisitions (M&As) and contracted R&D, all of which should be combined with in-house R&D efforts. Given these channels, the goal of lower-income groups must be to establish competitive export industries, whereas middle-income groups must focus on the consolidation of a local basis for knowledge creation and diffusion.

Table 2. Dynamics of industrial policy from low- to middle-income and beyond the middle-income trap

Stages	Low or lower-middle income	Upper-middle income toward high income
Policy tools	Industrial policy: (tariffs, undervaluation of currency, entry control)	Technology policy (public-private R&D consortium, R&D subsidies, standardization policy)
Access to External/Foreign knowledge	FDI, OEM/ Assembly work/ Licensing	Collaboration with public research labs and universities, Overseas R&D outposts, International M&As, contracted R&D (based on in-house R&D efforts)
Type of specialization	Trade specialization	Technology specialization
Criterion of Specialization	Labor or resource-intensive industries	Short cycle/emerging technologies
End goal	Competitive export industries	Indigenous knowledge creation and diffusion
Background theory	Product life cycle (inheriting)	Catch-up cycle (leapfrogging)

Source: the author.

2) Cycle Time of Technologies as a Criterion for Technology Targeting

A remaining concern is the nature and criterion of specialization, which is one of the classical issues in industrial policy. There is an established answer for the low-income groups: specialization based on initial endowments, such as labor and natural resources or comparative advantages associated with resource endowments (Lin, 2012). These industries usually produce low-value-added or low-end goods in the global division of labor, which essentially resembles trade-based specialization.

Now, an intriguing issue is identifying the criterion of specialization that can be applied to the group of middle-income countries that strive to upgrade their industrial structure from low to higher value-added. Value-added per worker or labor productivity might be a criterion, but it is too general and there are too many sectors with similar levels of labor productivity. Lin's structural economics points out the need for dynamic comparative advantage, suggesting that latecomers should target the industries with latent comparative advantage or mature industries from the countries slightly ahead of them. Nevertheless, though this is a good practical guideline, we still need a more theoretically grounded criterion, or a more specific, differentiating criterion for middle- or higher-income countries attempting to mobilize new tools of technology policy. For example, suppose that a country is ready to form a private-public R&D consortium to develop certain technologies or products. In this case, one thorny issue is identifying which technologies or products to target. Korea or Taiwan actually faced this problem in the mid-1980s. Let us say that two possible choices are pharmaceuticals or semiconductors. Both types of products have a higher value-added component than the apparel or calculators these countries produced and exported in the 1970s.

This question of specialization has also been raised in Greenwald and Stiglitz (2012) as the question of which country endowments determine its comparative advantage when a country is advised to follow its (current or latent) comparative advantages. Greenwald and Stiglitz (2012) also suggest that a society's learning capacity is influenced by its knowledge after discarding capital, skilled labor, and even institutions that tend to be mobile. This criterion makes sense because learning capacity eventually determines a country's long-term competitiveness. The next question, then, is which sectors would have a greater degree of learning capacity.

Allow me to suggest the cycle time of technology as a criterion for the specialization of middle-income countries. Conceptually, the length of cycle time of technologies refers to the speed by which technologies change or become obsolete over time, causing new technologies to emerge more often. In the literature (e.g., Jaffe & Trajtenberg, 2002), the cycle time of technologies is measured by the mean citation lag, which is the time difference between the application year of the *citing* patent and that of the *cited* patents. A long cycle time indicates greater importance of old knowledge, hence the greater need for latecomers to study such knowledge. When knowledge in the field changes quickly (i.e., essentially meaning of short cycle time), the disadvantages for the latecomer might not be significant. Thus, it is advantageous for qualified latecomers to target and specialize in these sectors.

Technologies based on short cycle time possess two key properties, namely, the sector has less reliance on existing technologies, and it have a greater opportunity for the continued emergence of new technologies. New opportunities indicate more growth prospects, and less reliance on existing technologies may lead to the faster localization of a knowledge creation mechanism. In this sense, these sectors would be those with higher learning capacities as emphasized by Greenwald and Stiglitz (2012). Additionally, this criterion satisfies the condition of viable profitability and competitiveness. This is because it indicates lower entry barriers and the possibility of higher profitability brought about by fewer collisions with advanced countries' technologies, less royalty payments, and even first- or fast-mover advantages or product differentiation. If we apply this criterion to the issue of choice over two sectors, semiconductors with shorter cycle time should be chosen rather than pharmaceuticals that correspond to longer cycle technologies. Although this is an ex-post judgment, one can say that if Korea or Taiwan decided to target the pharmaceuticals sector in their industrial policy, either country would not have been as successful as it is now.

The validity of this argument and the criterion for specialization has been verified by extensive econometric analysis conducted by Lee (2013a) at the firm, sector, and country levels. The findings are as follows. First, at the firm-level comparative analysis of Korean and American firms, the former tend to specialize in technologies based on short cycle time, which are linked to higher profitability. At the sector level, the question was identification of the fields in which technological catch-up may or may not occur, as well as the factors that influence the speed of technological catch-up. It was found that this occurs in the fields with shorter cycle times, and that the advanced countries tend to have a higher share in long-cycle technology-based sectors. At the country level, it was found that the successful catching-up countries, such as Korea, Taiwan, Hong Kong and Singapore, used to have longer or similar cycle time technologies as the high- and other middle-income countries until the mid-1980s. However, the cycle times of their patent portfolios began to shorten significantly since then. Country panel analysis confirms that specialization in technologies with shorter cycle times is positively related to economic growth in the successful catching-up economies of Asia, whereas growth is associated with specialization in technologies with long cycle times in both high- and other middle-income countries (excluding the Asian four).

4. How to Enhance the Capabilities of Firms in Developing Countries

This section focuses on the issue of how to move away from long-cycle to short-cycle technology-based sectors, or from the low value-added segment to the higher valued-added segment in the same industries. Such a transition does not occur automatically even if a country is open to trade and FDI. Rather, it always involves deliberate learning and risk-taking by companies and other public actors, combined with the exogenously open windows of opportunity. Short-cycle technology-based sectors matter because these are where new opportunities emerge more frequently and where business activities take place with lower entry barriers. The market mechanism serves not as a triggering factor but as a facilitating factor that stimulates risk-taking and rewards the successful actors.

For example, Taiwan's successful settling down with shorter-cycle technology-based sectors or higher value-added industry segments would have taken a longer time had there been no public-private R&D cooperation, the first successful example of which is the consortium to develop laptop computers (Mathews 2002). However, we should note that there were several attempts and failures prior to this achievement. Such private-private joint effort does not guarantee immediate success, but is the only way out of the old specialization in longer-cycle technology-based sectors, and hence, out of the middle-income trap. In Korean history, the first case of a successful public-private R&D consortium was the development of digital telephone switches. This marked the beginning of the country's emergence as a leader in telecommunication and IT devices, because that success was the source of learning and confidence that, in turn, led to further public-private cooperation in the production of memory chips, mobile phones, and digital TVs. With this series of public-private R&D collaborations to enter new industries, Korea gradually reduced its reliance on longer-cycle technology-based industries that produce such goods as apparel, textiles, processed sugar, radios, cookers, ovens, refrigerators, and other consumer products.

The following section describes the three-step process of entering and specializing in shorter-cycle technology-based sectors.[3]

1) Licensing/transfer/FDI-based learning to build initial absorptive capacity

Since the publication of the influential article by Cohen and Levinthal (1990), absorptive capacity has come to be recognized as one of the major binding constraints of economic development of the latecomers. Specifically in the case of Korea, scholars have emphasized the importance of absorptive capacity that has enabled companies to learn and assimilate the inflow of external knowledge (Evenson &Westphal, 1995; Pack, 1992; Kim and Dahlman, 1992). Efforts to build up such capacity

[3] For a fuller detail, see chapter 7 of Lee (2013a).

should focus on not only enhancing the level of generic human capital but also providing learning opportunities for workers in private firms. The Korean experience verifies this point.

In the 1960s, when Korea began to modernize with export drives, its human capital base was poor: in 1965, enrolment rates in the primary, secondary, and tertiary schools were 29.6 percent, 10.9 percent and a mere 2.6 percent, respectively. Thus, the main emphasis was on increasing the general level of human capital, so that by the mid-1970s, there was considerable improvement compared with the previous decade. In 1975, primary school enrolment rose to 106.86 percent and those for secondary and tertiary schools were 56.35 percent and 6.9 percent, respectively (World Bank, 2005).

The other aspect of enhancing absorptive capacity was increasing the imports of technology embodied in equipment, combined with training to acquire the know-how and skills needed to operate the imported facilities. Korean firms, especially during the 1960s and 1970s, chose to acquire know-how (tacit knowledge) that could help them construct and operate manufacturing facilities with which they were initially unfamiliar (Chung & Lee, 2011). The typical know-how bundle consisted of technological contents in printed form as well as related training and services provided on site by expatriate engineers. Korean engineers were occasionally sent to the transferor's firm to learn the implementation process. According to Chung and Lee (2011), the technology inclusive of patent rights would come later, when Koreans already gained better capabilities to decipher the codified contents of the patents.

Chung and Lee (2011) show through firm-level data on know-how licensing that Korean firms actually went through a lengthy period of learning, assimilating, and adapting foreign technology in the 1970s before beginning to conduct in-house R&D in the mid-1980s. Specifically, foreign technology flowed into Korea in three forms: licensing contract of know-how, patented know-how, and licensing of patented technology. Chung and Lee (2011), based on the cases of the leading Korean firms, shows the phases of foreign technology acquisition, leading to in-house R&D and own patent applications. In the case of LG Electronics, it was in 1969 (the year of its establishment) that it contracted for know-how licensing, followed by know-how plus patents, and then patent-only licensing. It first recorded its R&D expenditure in its financial statement for 1976, and filed for patent applications in 1978. This seems to be the typical sequence followed by Korean companies although there have been certain variations.

Another important means by which to enhance absorptive capacity is to set up public research institutes that can conduct R&D and problem-focused development, and then transfer the outcome to the private sector. For example, in the late 1960s, the Korean government recognized the need for advanced training for scientists and engineers in preparation for the development of indigenous technologies. In 1972, the government established a new graduate school of engineering and applied sciences, the Korea Advanced Institute of Science (KAIS), which was later renamed the Korea Advanced Institute of Science and Technology (KAIST). This academic institution has served as a vital scientific and technological institute that ensures, with adequate research funding, excellent education for the best minds of Korea.

Finally, establishing joint ventures with foreign partners or working in an OEM assembly arrangement with foreign firms is also an effective channel for learning basic operational skills and production technologies (Hobday, 2005). Attracting FDI is one of the best strategies to guarantee learning and access to knowledge. However, it may not be reliable for longer-term purposes, and there are certain conditions that must be met, including local controllership and local content requirements. Amsden and Chu (2003) state that technological catch-up requires the use of assets related to project execution, product engineering, and a form of R&D that straddles applied research and exploratory development. If such assets are to be accumulated at all, the responsible party tends to be a nationally owned organization. By its nature, FDI firms have no reason or incentive to develop their own development capabilities in host countries, because these reside in the mother companies abroad. Thus, ownership matter at least in R&D, and FDI might not be effective as a device with which to learn higher-tier capabilities (e.g., R&D). In their early days, many Korean chaebols had FDI or OEM relationships with foreign MNCs. According to Lee and He (2009), during its early days, Samsung Electronics was a joint venture with the Japanese firm, Sanyo, from which the Korean company – having no prior experience in the electronics industry – acquired know-how and technologies. Meanwhile, Hyundai Motors was an OEM assembler for the US-based Ford, although it soon broke up with the latter. Taiwan's path from OEM to OBM via ODM also involved a great deal of interaction with foreign firms in FDI.

2) Learning R&D Capabilities in In-house R&D and as a Co-R&D Partner

Once a firm builds a certain level of absorptive capacity, it must establish and initiate its own in-house R&D center. Independent R&D efforts are required because foreign firms would become increasingly reluctant to grant technology licenses to the rising latecomer firms, especially when the latter attempt to enter the skill-intensive markets dominated by the advanced countries. Thus, investment in R&D is required not only for the further absorption of advanced technology, but also for the development of the latecomers' own technological capabilities. Developing in-house R&D capabilities is critical also because the initial success leads to an increase in local wage rates, resulting in losing competitiveness compared to other economies offering cheaper costs or wages (Lee and Mathews, 2012).

With the establishment of in-house R&D labs, the firms at this stage have to explore more diverse channels of learning and access to foreign knowledge arise from licensing. The new alternatives include co-development contracts with foreign R&D specialist firms and/or with public R&D institutes, gaining mastery of the existing literature, setting up overseas R&D outposts, and initiating international M&As. For example, it was also from the early 1990s that a small number of Korean firms began to establish overseas R&D posts, mainly to obtain easy and faster access to foreign technology that used to be difficult to acquire through licensing. These overseas posts also served as a window on recent trends in technological development (OECD, 1996).

Arranging access to foreign knowledge and trying new modes of learning is critical, because isolated in-house R&D efforts are often insufficient to build indigenous R&D capabilities. In this regard, allow me to elaborate on the two important modes of new learning at this stage: 1) co-development contracts with foreign/external R&D specialist agencies or firms, and 2) participation in a public-private R&D consortium. In both cases, the best targets for R&D are those industries or technologies that are relatively mature, but which the latecomer economies are importing or buying at monopoly prices from foreign companies. In this situation, import-substitution targeting involves taking the rents away from the foreign companies and giving them to the local companies. In this scheme, local efforts face fewer uncertainties or risks, because the targeted technologies are often mature ones that are not impossible to emulate through the concerted effort of the local R&D consortium. One reason that could hinder targeting is the uncertainty involved in making the right choices in industries or technologies. For example, no one can tell which industries or technologies will prosper in a particular country. This concern makes more sense in the context of developed countries, where firms at the forefront of technologies face greater uncertainties. In the context of the latecomers who are below the frontier, a ready justification for targeting industries exists.

A good example of the first mode (co-development) is the case of Hyundai Motors of Korea. The main business of the Hyundai group used to be construction, a long-cycle technology-based sector. Hyundai entered the shorter-cycle business of automobiles in the early 1970s as an assembly maker for Ford, the US car manufacturer. Such a story is common in developing countries. However, Hyundai Motors and Korea's current status as stronghold of the automobile business would not have been possible without the company's brave decision to cut its ties with Ford and to sell its own brand of automobiles equipped with its own engines. Hyundai then became a joint venture with the Japanese car maker, Mitsubishi, wherein the Japanese company provided engines and other key components, while Hyundai merely assembled them. In that partnership, Hyundai was a licensed producer but not an OEM producer, as it used its own brand in the local and export markets. However, when Hyundai wanted to develop its own engines, Mitsubishi (which held 20 percent of the equity) refused to teach the former how to design and produce these engines on its own. Most developing country businessmen would have given up at that point, but Hyundai's founding chairman, Chung Ju-yung, did not. He decided to spend an enormous amount of money on R&D, with efforts focused on engine development.[4] Fortunately, Hyundai was then able to gain access to the external knowledge of specialized R&D firms, such as Ricardo in England. The process was not easy; Ricardo did not just provide an engine design. It was basically a co-development of a completely new design by the two companies. In fact, the partners had to try more than 1,000 prototypes until they finally succeeded seven years after the project was launched in 1984 (Lee and Lim 2001).

The second mode, participation in a public-private R&D consortium, can also be an effective school for private firms when their capability is low. Given their low R&D capabilities, the private firms cannot take the lead in the consortium, in which public research agencies play the key R&D roles and teach and transfer the outcomes to participating private firms. We can find many examples of this process from Korea, Taiwan, and other catching-up countries.

A noteworthy example would be the government-led R&D consortia in the telecommunication equipment industry, specifically the accompanying local development of telephone switches. This led to the successful localization of telephone switches in the 1980s and 1990s in several latecomer countries, including China, Korea, India, and Brazil (Lee, Manil, & Mu, 2012). Most of the developing countries used to have serious telephone service bottlenecks in the 1970s and 1980s; they had neither their own telecommunication manufacturing equipment industry nor their own R&D program. As a result, they used to import expensive equipment and related technologies, and local

[4] For details on the history of Hyundai Motors, see Lee and Lim (2001).

technicians merely installed foreign switching systems into the country's domestic telephone networks. With industrial and commercial bases developing rapidly – along with population growth – a number of countries decided to build their own manufacturing capabilities.

Starting with Brazil in the 1970s, followed by Korea and India in the mid-1980s, and finally by China toward the late 1980s, all of these countries crafted a state-led system of innovation in the telecommunication equipment industry, with a government research institute at the core. The research institute developed more or less "indigenous" digital telephone switches that were then licensed to public and private domestic enterprises. In these four countries, a common pattern in the indigenous development of digital switches was the tripartite R&D consortium among the government research institutes (GRIs) in charge of R&D functions, state-owned enterprises (SOEs) or the ministry in charge of financing and coordination, and private companies in charge of manufacturing at the initial or later stages. However, the subsequent waves of industry privatization and market liberalization in Brazil and India versus the consistent infant industry protection in Korea and China differentiated the trajectory of the industries in these four countries (Lee, Manil, & Mu, 2012). At one extreme, the indigenous manufacturers of China and Korea took over from the importers and MNCs. Their enhanced capabilities in wired telecommunication, which were accumulated over the preceding decades, led to the growth of indigenous capabilities in wireless telecommunication as well. At the other extreme, Brazil and India have increasingly become net importers of telecom equipment, and their industries are now dominated by affiliates of the MNCs.

As noted by Lee and Mathews (2002), examples from Taiwan include the cases of calculator and laptop PC production. The calculator case is an example of the acquisition of more fundamental design capability or the basic design platform, which is made possible with the help of a government entity such as the Industrial Technology Research Institute (ITRI). Another example is the public-private R&D consortium to develop laptop PCs from 1990 to 1991(Mathews, 2002). This consortium developed a common mechanical architecture for a prototype that could easily translate into a series of mass-produced standardized components. The consortium represented an industry watershed, and even after several failed attempts, it succeeded in establishing new "fast follower" industries in Taiwan.

3) Final Stage of Learning: Leapfrogging into Shorter-Cycle Sectors

The final stage is leapfrogging, in which the latecomers do not aim to imitate the existing products or plants, but explore ways to develop emerging products in short-cycle technologies. A Korean example is digital TV development, which can be regarded as the decisive and final watershed that enabled Korea to begin taking over Japan in the TV business. An example from China would be its recent move toward electric-engine cars and the use of solar power. In these areas, there are no products to imitate from the latecomers' point-of-view; instead, the advanced and latecomer countries enter the market at the same time. If the former latecomers succeed first, there would be a strong momentum for them to surpass the middle-income group and join the rich country club. In this leapfrogging endeavor, the public-private R&D consortium takes a more vital role given that the risk involved is huge and different. Furthermore, coordinated initiatives for exclusive standards and incentives for early adopters would be important in reducing the risk faced by the weak initial market.

Although both of the second and third stages involve the public-private R&D consortium, there is a marked difference between the two. In the third stage, private firms take the lead over the public labs in conducting R&D jointly, whereas in the second stage, public research labs are mainly in charge of R&D, with the private actors doing the manufacturing. Thus, in the final stage of the R&D consortium, the role of public research arms is to monitor the trend of technologies as well as to provide information and knowledge about the choice of proper technology standards and the identification of suitable foreign partners in collaborative development. Examples of the foreign partner include Qualcomm for mobile phone development and Zenith for digital TV development. Furthermore, a foreign company usually has a different role. In the second stage, the foreign company is the direct teacher in the co-development contract; however, in the final stage, it becomes the supplier of source technology to be commercialized by the latecomer firms or their consortium. This has been case with Korea's entry into the mobile phone or digital TV market (Lee et al., 2005). In terms of relationships with foreign actors, the final stage features horizontal collaboration or alliance based on complementary assets. Some Korean firms (e.g., Samsung) have reached this stage, and are now engaged with Intel, Sony, Toshiba, and Microsoft in diverse modes of alliances.

In light of the above, the success probability of leapfrogging may be higher when a new techno-economic paradigm or a new generation of technologies begins to emerge. Perez and Soete (1988) and Freeman and Soete (1997) observe that some latecomers may be able to leapfrog older versions of technology, bypass heavy investments in previous technology systems, and jump on new technologies to take over the market from the incumbent firms or countries. This leapfrogging strategy makes more sense at the time of a paradigm shift, because every country or firm is a beginner in using the new techno-economic paradigm, and the entry barriers tend to be low. Furthermore, the so-called winner's trap may operate in the sense that the incumbent tends to ignore new technologies and continue to use the existing dominant technologies until it exhausts its sunk investment in the existing facility. The concept of leapfrogging is consistent with the idea of technological discontinuity proposed by Anderson and Tushman (1990) and Tushman and Anderson (;1986) that competence-destroying discontinuity may lead to the emergence of new entrants.

Korea's catch-up with Japan in the development of high-definition TVs (HDTVs) would not have been successful if Korean electronics companies, such as Samsung and LG, did not target the emerging digital technology-based products more aggressively than Japanese companies that opted to continue manufacturing the dominant analogue products.[5] The Japanese firms developed, for the first time, the analogue-based HDTV in the late 1980s, and suggested that Korean companies follow new technologies and products by learning from them. Initially, the Korean companies considered going in that direction as they used to do in the 1970s and 1980s. Instead, they decided to try a leapfrogging strategy of developing an alternative and emerging technology, i.e., producing digital technology-based HDTVs. These companies succeeded by forming the public-private R&D consortium, which marked the beginning of the Korean hegemony in the global display market previously dominated by Japan. Without such risk-taking and leapfrogging strategies, Korean catch-up with Japan would have taken much longer or might have never happened.

Leapfrogging is more likely to happen when there are more frequent changes in technologies or generation changes in products, and when there are certain technological sectors with such features. As argued, such features are closely linked with the length of the cycle time of technologies, as they indicate the speed with which technologies change or become obsolete over time, paving the way for the continued emergence of new technologies. We can reason that it is advantageous for qualified latecomers to target and specialize in such sectors. Although this is considered a risky venture, it would prove to be a logical one because the latecomers do not have to rely substantially on the existing technologies dominated by the incumbents; moreover, there are always more growth opportunities associated with ever-emerging technologies.

Finally, we should note the importance of carefully handling the risks involved in opting to implement the leapfrogging strategy. As Lee et al. (2005) explains, one of the biggest risks is

[5] The case of digital TV production is further explained by Lee et al. (2005). A direct comparison of Samsung and Sony can be found in the work of Joo and Lee (2010).

choosing the right technologies or standard in the ex-post sense. In the competition for standard setting and market creation, the role of the government is to facilitate the adoption of specific standards, thereby influencing the formation of markets at the right time. In general, when the involved target is in the area of information or another emerging technology, the critical function of standard setting should be emphasized. Aiming to achieve isolated development without consideration for standards might lead to a failure of the entire project. In a standard setting, collaboration and partnership with rivals or suppliers of complementary products are essential. Another key factor is determining who creates and reaches the market first, given the fact that market size determines the success or failure of one standard in relation to another.

4) Summary of the Process[6]

This section summarizes the entire process of moving from longer-cycle to shorter-cycle technology-based sectors.

Let us suppose an initial stage, in which the latecomer countries tend to specialize in longer-cycle technology-based sectors or in the low-end segment of the relatively short-cycle technology-based sectors. An example of longer-cycle technology-based sectors is textile products. An example of the low-end or low value-added segment of the shorter-cycle technology based sectors is the OEM- or FDI-based assembly-type products in consumer electronics or automobiles. These arrangements are typical of low-income or several middle-income countries. Although the longer-term prospect of this model is somewhat uncertain, it tends to promote economic growth, which is sometimes accompanied by protectionist measures in the form of tariffs and undervaluation of local currencies.

At this stage, the goal of industrial policy is to prioritize job creation and output growth rather than technological learning. Thus, policy tools often include tariffs and undervaluation of currencies that are less sector-specific or horizontal than tools, such as targeting certain technologies in the form of specific R&D grants or projects. Other forms of horizontal intervention are needed in the areas of hard infrastructure (e.g., transportation, energy and communication), although these would not be classified as industrial policy in a narrow sense. If any degree of specialization is needed, the traditional criterion of comparative advantage along with resource endowments would suffice.

[6] This sub-section is based on chapter 7 of Lee (2013a).

When a country reaches middle-income status, it would need greater sector-specific or vertical intervention because it must now identify its niche between low- and high-income countries, with limited options than before. At this stage, industrial policy becomes less concerned with job creation but more focused on the creation of or entry into new industries to upgrade the overall industrial structure.

This paper suggests short-cycle technology-based sectors as a niche for latecomers. Although this criterion does not guarantee success in the deterministic sense, it is more likely to lead to success under certain conditions. In other words, one critical factor that must be considered is how to break into shorter-cycle technology-based products or into the higher-valued segment of the existing short-cycle technology-based sectors. This transition involves moving from the license-based production of consumer products to their own design (IPRs)-based production. Good targets for such an entry are those products that the latecomers were unable to manufacture but had to import at higher prices due to their economic significance. For example, for Nigeria or Cameroon, which produce oil but export it as crude oil without refining it for higher value-added quality, the target should be to build an oil refinery in their respective countries. The task is not impossible given that the technology needed to build an oil refinery is old and mature and is, therefore, easily available at cost. Its nature is similar to Korea's decision to build its own steel industry in the early 1970s because it did not want to pay higher prices for steel products to be used by local steel-consuming industries, and instead wanted to promote products such as automobiles and ships. A recent example is China's move to target and develop high-speed trains as a latecomer. As a large nation, China needs such a transportation system, and it would incur substantial costs if it would continue to rely on foreign technology rather produce its own trains.

In terms of policy tools, this indigenous endeavor tends to involve R&D grants and collaboration with public or foreign partners, combined with infant industry protection in the form of sector-specific tariffs and credits or public procurement. By contrast, undervaluation of currencies would not be effective, because it is not discriminatory enough. In other words, it is now time to look for sectors in which to invest the rents earned through undervaluation in the preceding stage.

The final stage of leapfrogging involves public-private R&D efforts that target emerging, rather than existing, technologies. In this case, the role of the government and public labs is to share the risk involved in the choice of technologies and to promote the initial markets. Specifically, coordinated initiatives on exclusive standards and incentives for early adopters would be essential in reducing the risk faced by the weak initial market.

Throughout the stages of leapfrogging, it is necessary for the latecomers to gain access to a foreign knowledge base, without which their endeavors would be more difficult and are likely to fail. The latecomers can and should utilize diverse access channels, such as tacit knowledge held by specialized R&D firms or individual scientists or engineers in universities in the form of contracts, reverse brain drains, and/or overseas R&D outposts (Lee, 2005). To imitate existing product designs or concepts, the latecomer firms may have to rely on the memory of those who are previously involved in the R&D projects of the forerunning companies. Of course, the latecomers also have to rely on explicit knowledge in the form of licensing, literature, or other forms of public knowledge. The idea that the dynamic process of learning capabilities requires matching with different teachers (learning sources) is also a key aspect of the capability-based view of industrial policy.

5. Summary and Concluding Remarks

This paper began with a theoretical distinction of market, system, and capability failure as a justification for industrial policy. Although these concepts have varying degrees of relevance in different contexts, this paper argues that capability failure is the most serious and unique problem in the context of developing countries compared with developed economies. This paper also identifies failure of capability, especially technological capability, as the source of the middle-income trap faced by many developing countries as they attempt to upgrade to higher value-added industries or segments. As a solution to this problem, this paper proposes technology-based specialization and elaborates on how to build the necessary capability.

In the literature, a low-income country is advised to follow trade-based specialization to exploit the comparative advantages associated with its natural resources. In this manner, such countries can command international competitiveness in certain industries, which are typically inherited from higher-income countries. This process is predicted by the product life-cycle theory (Vernon, 1966). Along this line, low-income countries may grow to reach middle-income status. However, the medium-term risk to the initial comparative advantage of industries operating in these countries is associated with wage rate increases in the labor-intensive industries that are dependent on low wages. By comparison, new and cheaper labor sites in next-tier countries are always at hand, ready to emerge and assume previously occupied by their predecessors in the global value chain. Thus, so-far successful latecomers may be falling into the middle-income trap associated with the so-called adding-up problem. Thus, a long-term challenge for low-income countries is to move to higher value-added activities in the same industries and/or gain entry to newly emerging industries.

For a developing country to go beyond the middle-income stage, this paper suggests the implementation of technological specialization in a shorter cycle or in emerging technologies, or finding an upgraded niche in a new value segment in the current industries. The empirical analysis in the work of Lee (2013a) shows that the successful catching-up economies and their firms have specialized in short-cycle technologies, thereby promoting a higher degree of localization of knowledge diffusion and creation. This strategy has also allowed the successful catching-up countries to upgrade further based on their indigenous capabilities. This strategy makes sense due to the fact that in sectors with shorter technology cycle times, new technologies emerge frequently and existing ones become obsolete quickly. Thus, the latecomers do not have to master existing technologies dominated by the incumbent. In fact, advanced countries tend to be more active in sectors with longer cycle times. A complementary relationship also exists between specialization in short-cycle technologies and localization of the knowledge creation mechanism, because using short-cycle technologies means relying less on existing technologies dominated by incumbent advanced countries.

This paper suggests an implementation strategy to facilitate the transition from trade-based specialization to technology specialization. The goal is to acquire technological and design capabilities based on a combination of acquired external knowledge and in-house R&D efforts. Three stages are described herein. The first stage involves the assimilation of foreign technology (mostly operational skills and production technology) and know-how (through licensing, OEM or FDI arrangements) or technology transfer from public research agencies. In the second stage, the learning and access channels change to co-development contracts and public-private consortia once the latecomer firms establish their own in-house R&D labs as a physical basis for more indigenous learning. In this stage, the R&D target can be mature segments in the short-cycle technology sectors, which translate into fewer uncertainties in terms of feasibility and market potential. The varied experiences in the production of telephone switches in China, India, Brazil, and Korea comprise the prime example. The final stage of learning is the more ambitious strategy of leapfrogging to emerging technologies, with digital TV development in Korea or indigenous 3G wireless standard development in China as the examples. When technological specialization involves leapfrogging, two kinds of risk may be involved: whether or not the countries are making a right choice over technologies or standards, and whether or not there is an initial market for these technologies. Thus, gaining entry into new, emerging industries must involve government assistance in the form of technological policies that guide public-private R&D consortia and/or exclusive standard policy, procurement, and user subsidies for initial market provision.

One might ask whether or not it makes sense to say that every middle-income country should specialize in the same short-cycle technologies. This question is analogous to the question of the adding-up problem, which refers to the risks involved in the strategy of labor-intensive specialization in all low-income countries. However, specialization in short-cycle technologies does not entail a fixed list of technologies; instead, the sectors with short-cycle technologies imply the fields or sectors, in which new technologies always emerge to replace obsolete ones. The continuous emergence of new technologies suggests the availability of new opportunities for new entrants that are not confined to the old dominant technologies. This idea is contrary to the concept of the product life cycle, in which latecomers only inherit old or mature industries or segments from the incumbent economies. If industrial policy is akin to a concentrated commitment of resources into certain sectors to obtain returns and improve a sector's chances of success, then choosing long-cycle technologies means would mean a reduced chance of success. This is because such technologies require more resources, thereby requiring more time to build a minimal level of competitiveness required for international competition.[7] For example, had Korea decided to enter the pharmaceuticals market in the 1980s, it would not have become successful not only in that industry itself, but also in terms of the growth of related industries and subsequent entries into newer ones.

Finally, we should point out the double-edged nature of short-cycle or frequently changing technologies, that is, they can serve either as windows of opportunity or as additional barriers to entry. Although Korea and Taiwan achieved successful catching-up in short-cycle sectors, other lower-tier countries, such as those in Latin America, did not experience success in those sectors (Lee, 2013a). This condition has to do with the notion of truncated learning (Lall, 2000), in which frequent technological changes interfere with the effectiveness of learning, and acquired knowledge becomes obsolete or useless with the advent of new technologies. This explains why the proposal in this paper

[7] Certainly, if we are concerned only with domestic markets that are more or less closed to competition, the significance of a short or long cycle might not matter as much as it does with the present discussion.

involves a three-stage entry into shorter-cycle-based sectors, focused on the gradual development of capabilities. Entry into the next stage requires the successful accumulation of capabilities in the preceding stage. Although this is a narrow path rife with risks and requirements, it is the only available way toward high-income country status.

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