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Principles and Methodologies for STI Strategy Development: Experience and Best Practices from the Republic of Korea

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Abstracts This paper articulates the STI strategy development principles and methodologies that have been elaborated through iterative processes of STI strategy development cases for the past ten years. The consultation cases include poverty traps in Nepal and Laos, African health challenges in Nigeria and Tanzania, and ASEAN global challenges in Indonesian Water, Vietnamese Green Energy, and Filipino Food, in partnership with some multilateral agencies.The iterative elaboration process has continued with consultation activities on Thailand and on Cambodia, Laos and Myanmar in planning partnership with Thailand. The principles were originally conceptualized from the benchmarking process of the Korean STI development experience. They were further incorporated as methodologies with which relevant planning bodies are guided to address individual and regional challenges through science, technology and innovation strategies. The methodologies are strong in providing plausible holistic perspective scenarios by which various stakeholders can be engaged in the planning and implementation process. But it is heuristic in nature and can be learned only through on-the-job training process. This is the structural limitation for scaling up.

Keywords Principles, methodologies, STI strategy development, benchmarking Korean experience, planning partnerships

I. Benchmarking Process and Components: Vision, Driving Mechanism and Implementation

Korea's STI development experience is widely acknowledged as representing best practices, not only by least developed and developing countries, but also by OECD countries (OECD, 2014). They are characterized with ownership and capacity development through which endemic and systemic poverty was successfully overcome. These are the principles of the

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UN system, which is now under transition from the Millennium Development Goals (MDGs) to the Sustainable Development Goals (SDGs). STI strategies can be designed as sustainable growth drivers for least developed and developing countries as the Korean experience is appropriately contextualized and poverty can be effectively addressed, which has not been solved with direct and separate solutions (figure 1).

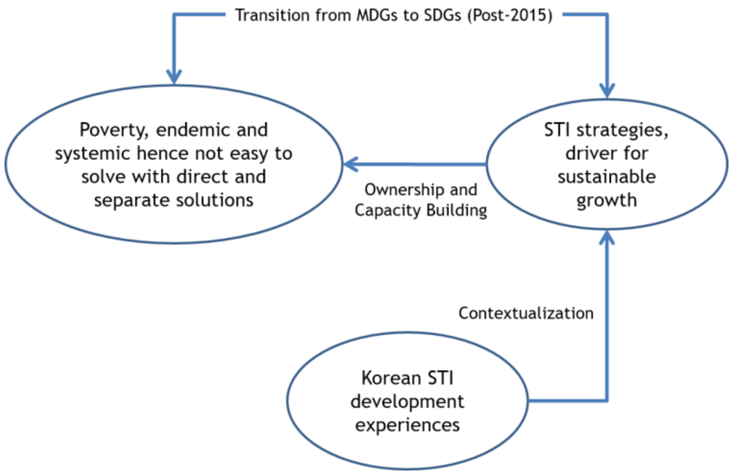


Figure 1 Position and characteristics of Korean STI development experience in the global challenge issues

OECD countries are also trying to benchmark the Korean experience as most of them are challenged to promote new industries and create qualified jobs with limited fiscal instruments especially since the 2008 global financial turbulence and also deal with global challenges of climate change and others, which are beyond individual countries' capabilities. Their policies are mostly aligned with market fine-tuning, but industrial promotion was avoided for several decades. Korea is the only country whose policy experience is still embodied in the government practices and steered through a collective mechanism that is relevant for addressing global challenges.

There are two globally acknowledged practices of consultation - global standard by American consulting companies and benchmarking practices of OECD. The first one is losing its relevance since China began to dominate the global economy, so the one-sided application of global standard, which is the American standard, is no longer valid. Furthermore, the business-oriented consultation on global standard can be hardly converted into government policies in a market where few global consulting companies are entering. Their policy recommendations are naturally lacking relevance and hence not easy to implement.

The benchmarking process normally starts with identifying own problems for benchmarking; it continues with surveying and visiting best practices, and it articulates new practices for implementation. OECD uses the benchmarking practices comprehensively as it consults OECD and non-OECD countries. It compares the target countries' performance with that of other (OECD) countries by innovation system component criteria and it recommends an increase above the average if they are below that average and the implementation of certain policy practices used by other better performing countries. This type of benchmarking lacks a longitudinal approach by which specific solutions are articulated to solve identified problems, and it does not tell how to design and implement relevant programs.

Korea's STI development experience is uniquely positioned to articulate alternative solutions, but used mistakenly. Strategic focus, public research institute system, national research consortia, and supply chain localization are a few of Korean best practices. They cannot be effective if they are implemented without contextualized understanding of the principles of decision-making, implementation vehicle design, resource allocation and management. This paper endeavors to articulate new approaches for system diagnosis and STI strategy development with appropriately benchmarking the Korean experience.

This was triggered as the Science and Technology Policy Institute (STEPI) team, led by Lee, who consulted Vietnam's Ministry of Science and Technology to prepare a five-year Science and Technology Plan (Lee et al, 2008). It was natural for STEPI experts to propose problem-solving programs in the context of structural bottlenecks in Vietnam. Vietnamese partners wondered what methodologies were used to articulate them. The principles and methodologies were elaborated further since then as the team continued to intensively consult on poverty traps in Nepal (2012) and Laos (2013-2014) in partnership with the UN-ESCAP Asian and Pacific Centre for Transfer of Technology (APCTT), African health challenges in Nigeria (2013) and Tanzania (2013) with the participation of WHO-initiated African Network for Drugs and Diagnostics Innovation (ANDI) and ASEAN global challenges (2013-2014) in Indonesian Water, Vietnamese Green Energy, and Filipino Food[1]. Currently, this has been used in the Science, Technology and Innovation Policy Institute (STIPI) of Thailand since July 2016 and the STIPI

[1] The seven country consultation results can be referred to Lee, Maliphol and Yang (2013), Lee, Maliphol, Sun, Yang and Dong (2013), Lee, Maliphol and Kang (2014), Lee, Maliphol and Kim (2015).

has extended its planning partnership with neighboring countries of Cambodia, Laos and Myanmar.

Those countries have common problems of vague and irrelevant futuristic vision, absence of driving mechanism and poor implantation. First, their visions are just "wish list" of STI to address their socio-economic and global challenges. This wish list vision is also typically found in most APEC countries[2]. Secondly, the driving mechanism is absent to coordinate various stakeholders of nations, regions, and individual STI actors to work together to achieve collective goals. Thirdly, implementation is deterred by the lack of longitudinal approaches and prevalence of benchmarking practices leading to intrinsic conflicts of implementation. Once implemented, specific programs/ projects are not relevant, coherent or consistent to achieve goals especially with bottom-up competition processes.

European Research Area (ERA) vision and smart specialization mechanism are different from other practices (Lee, 2011a). The ERA vision was conceptualized with specific diagnosis of European scale economy problems as it competes with the USA and China for research institutes of global companies. Smart specialization was designed as a driving mechanism to achieve the vision by which each sub-national regions of Europe can be specialized according to their advantages and talents that embody knowledge circulating among the regions integrate them in one region. A smart specialization plan is required as an ex-ante condition for European funding. Though the concept is based on the specific European context, its relevance is not clear as for the impact to create the scale economy of Europe. The complexity of stakeholders is one of the potential bottlenecks for impactful implementation.

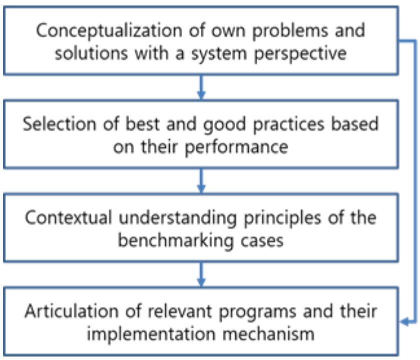


Figure 2 Benchmarking process

[2]APEC member economies' STI strategies were critically reviewed and discussed during the APEC Research and Technology (ART) program from 2010 to 2012.

The iterative process of principle and methodology elaboration is benchmarking in nature with consultation cases. Benchmarking of the Korean experience is done after conceptualizing problems of the country system and solution articulation. It is thought that best and good practices of Korea cannot be copied, but their principles can be transplanted. And the principles can be used to design programs, their implementation mechanism (Figure 2) and framework conditions, and diagnosis-based goals, solutions and results are guiding components of benchmarking (Figure 3). With these benchmarking process and components, Korea’s STI development experience will be reviewed in the following chapter and the strategy development principles and methodology will be proposed later.

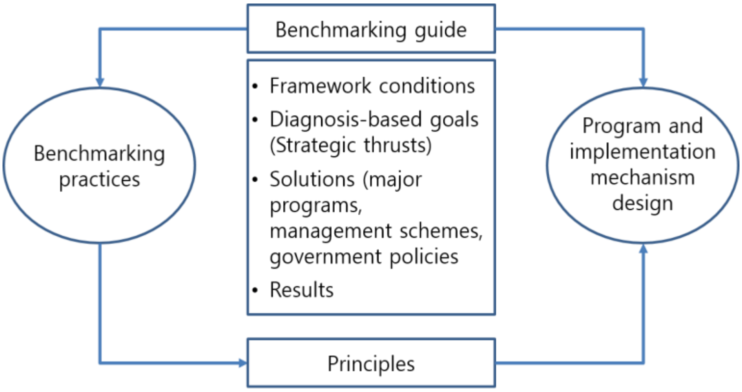


Figure 3 Benchmarking framework

II. The Korean STI Development Experience

This chapter reviews the Korean STI development trajectory every ten years from 1960s with the benchmarking guiding components – export promotion in 1960s, government research institute as technology windows in 1970s, research consortium as risk sharing mechanism and supply chain localization in 1980s, and research system promotion in 1990s and 2000s. The STI initiatives of Korea’s last three governments will be briefly examined as well.

1. Export Promotion in 1960s

Global companies were not interested in investing in Korea in 1960s as the country did not have natural resources and the domestic market was poor and small. Export promotion with diligent, cheap and well-motivated human resources was the only way to survive. Skill development with vocational training system and other macro-economic institutional settings were arranged to boost export promotion. Korea has dramatically increased export from USD100 million in 1960 to USD363.5 billion in 2010 (Table 1).

Export promotion has functioned as a kind of structural capacity[3] for industry to expand its partnership for further innovation investment in the next development phase. In the second half of 1960s, legal and administrative frameworks were institutionalized to promote capital intensive industries by establishing the Korea Institute of Science and Technology (KIST) (1966), the Ministry of Science and Technology (MOST) (1967), Science and Technology (S&T) Law (1967), and Long-term Master Plan for S&T Development.

Table 1 Framework conditions, goals and solutions in 1960s

	Descriptions
Framework Conditions	No natural resources, small and poor domestic market, only diligent, cheap and well-motivated human resources
Diagnosis-based Goal	Export promotion
Solutions	Vocational training system (1967) and macro-economic institutional settings such as low currency rate to boost export promotion
Results	Dramatic increase of export from 100 million USD in 1960 to 363.5 billion USD in 2010

2. Government Research Institute as Technology Windows Since 1970s

Six heavy and chemical industries were promoted in 1970s since Korea could not sustainably develop its economy solely with labor-intensive industries. They were steel and iron, machinery, shipbuilding, automotive, petrochemical, and electrical & electronics. The Korean government's proposal to establish steel and iron mill, which was an anchor facility to promote the heavy and chemical industries, was criticized by the IBRD economists. Those industries were dominated at that time by leading global

[3] Structural capacity can be provided through the strategic intervention of government when STI stakeholders are lacking actual capacities and do not need each other for collective collaboration (Lee, Maliphol and Kim, 2015, 22-23). Following Korean government interventions such as government research institute and research consortium can be considered as structural capacity building mechanisms by which STI stakeholders could achieve collective goals to benefit each other.

economies such as the USA, Germany and Japan. From the perspective of Korea, it was necessary and inevitable to sustain the economic development.

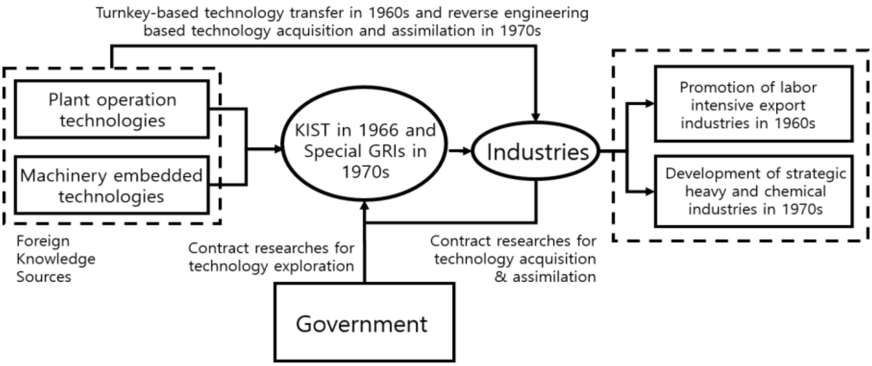
Korea did not have technologies, human resources and investment funding to develop strategic industries. Government research institutes (GRIs) were set up as technology acquisition and dissemination mechanism, and overseas Korean researchers and engineers were repatriated to manage the GRIs. Their missions were to absorb foreign technologies and convince private sectors to engage in technology development when they did not know technologies. To activate close relationship with private sectors, a project-based operation model was installed at GRIs. They were given full autonomy and authority to manage their research divisions with initial endowment. Before they spend all this endowment, they should have private funding for the operation of their divisions for which they have full responsibility. So, the GRI system did not have to have evaluation schemes. High caliber engineers were cultivated through the establishment of the Korea Advanced Institute of Science and Technology (KAIST). Strong government engagement and financing schemes to invest in the major strategic industries, including financial compensation, were appropriately arranged (Table 2).

Table 2 Framework conditions, goals and solutions in 1970s

	Descriptions
Framework Conditions	Structural weakness of export promotion of a labor intensive industry for sustaining industrial competitiveness with shrinking overseas assistance
Diagnosis-based Goal	Promotion of six heavy and chemical industries, but absence of technology, human resources and investment funding for industrial development
Solutions	Creation of government research institutes (GRIs) and repatriation of overseas Korean researchers and engineers for technology absorption and dissemination from overseas to domestic private sectors. Project-based operational models of GRIs to activate close relationship with private sectors Cultivation of high caliber engineers through establishment of KAIST Strong government engagement and financing schemes to invest in the major strategic industries including financial compensation
Results	In 2010, Korea's POSCO was ranked as the world's #1 steel and iron company, automotive industry was ranked fifth worldwide, petrochemicals comprised 7.6% of exports, machinery occupied 7.7% of exports and electronics totaled 25.1% of its exports.

With these strategic arrangements, Korea's POSCO ranked as the world's #1 steel and iron company, the automotive industry was ranked fifth worldwide, petrochemicals accounted for 7.6% of exports, machinery for 7.7% of exports and electronics for 25.1% of its exports in 2010.

Figure 4 shows the schematic mechanism of KIST and special Government Research Institutes (GRIs) for building up indigenous high-tech capabilities for labor-intensive export industrial promotion in 1960s and strategic heavy and chemical industry development in 1970s. Foreign knowledge sources of plant operation technologies and machinery embedded technologies were transferred to the Korean system through turnkey technology transfer in 1960s and reverse engineering technology acquisition and assimilation in 1970s. KIST and special GRIs were managed through contract researches for government technology exploration and private technology acquisition and assimilation.



Source:Lee and Saxenian (2013)

Figure 4 KIST and special GRIs for indigenous high tech capabilities

3. Research Consortium As Risk Sharing Mechanism and Supply Chain Localization Since 1980s

Korea’s large private companies have recognized the importance of technology development for their competitiveness in the global market from previous system development. Technology protectionism since the second oil crisis at the end of 1970s, however, has nullified the acquisition and dissemination model. Promotion of private R&D investment was necessary and facilitated by the government technology drive interventions (Table 3).

Semi-conductor was identified as an anchor technology to sustain the Korean electronics industry by a few large companies such as Samsung, Hyundai and later Goldstar (now LG). After Samsung succeeded to develop 64K DRAM in 1983, Japan and the USA began to hold it in check with anti-dumping duties, and the price of DRAM plunged from USD3 to USD0.30 in 1985. Nevertheless, Korean semi-conductor companies successfully managed to develop up to 1 Mega DRAM and almost caught up advanced countries. Uncertainties of technology development and market were bottlenecks to continue to develop 4 Mega DRAM (Kim, Baik and Park, 2015).

Research consortia of private companies, GRIs and top universities were designed to share the uncertainties with large private companies. The Electronics and Telecommunications Research Institute (ETRI) managed the three consortia of Samsung, Hyundai and LG. The 4 Mega D-RAM was developed in 1989, 16 Mega DRAM in 1990 and 64 Mega DRAM in 1992, the latter was the world's first (Kim, Baik and Park, 2015). This became the stepping-stone for Korean companies to take the leadership of the semi-conductor industry in the world. Seoul National University and later other top-ranking universities also joined the consortia, and graduate students who participated into the program later became the leading engineers of the semi-conductor industry.

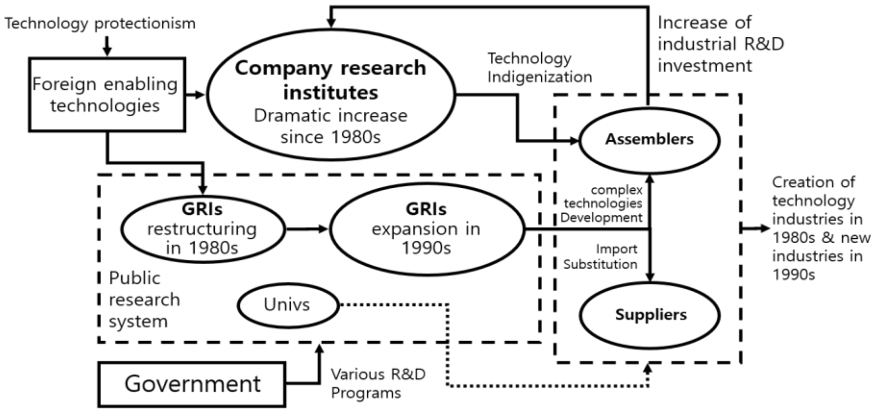
Table 3 Framework conditions, goal and solutions in 1980s

	Descriptions
Framework Conditions	Technology protectionism after oil crisis of late 1970s/wide recognition of R&D investment for private companies competitiveness
Diagnosis-based Goal	Promotion of private R&D investment and technology drive of government
Solutions	Research consortium of private companies, GRIs and universities by national R&D program (1982), Industrial Technology Development Program (1987), Information & Communication Technology Program (1988) Private R&D Promotion Schemes; R&D Tax Support (1981), Private Research Center Certification (1982), Tariffs Reduction on Research Materials (1983)
Results	Less than 20% R&D investment from private sector in 1980 to more than 80% in 1990 In 2010, Semi-conductor comprised 11% of exports/Display 6.4% of exports /Mobile phones 5.9% of exports

Various line Ministry R&D programs such as the National R&D Program (1982), the Industrial Technology Development Program (1987) and the Information & Communication Technology Program (1988) started in 1980s.Likewise, display and CDMA technologies were also developed by consortia, which led the Korean economy to successfully develop and produce products for the global market. In 2010, the semi-conductor industry was responsible for 11% of exports, the display sector for 6.4% of exports and mobile phones for 5.9% of exports.

Beside research consortia and ministerial R&D programs, the government provided various private R&D promotion schemes – R&D Tax Support (1981), Private Research Center Certification (1982), Tariffs Reduction on Research Materials (1983) and others. The companies that had certified research institutes could hire top university graduates as researchers since they were exempted from military service. With these interventions, R&D investment from private sector increased sharply from less than 20% in 1980 to more than 80% in 1990.

The semi-conductor development was conceived to substitute import from Japan. Later, the import substitution continued to facilitate the supply chain localization of the automotive sector.Various programs of pilot plant, technology extension and others have been designed to facilitate the import substitution and supply chain localization. The GRIs were restructured in1980s, but they expanded in 1990s. They mediated the complex technology development and import substitution process with the support of various line ministry R&D programs. Universities were geared to provide engineers and technicians to meet the rapidly growing human resource demands from industries.



Source: Lee and Saxenian (2013)

Figure 5 Company research institutes to drive the new technology product development

Private company research institutes began to increase in Korea and they led the creation of technology industries since 1980s (Figure5). They have successfully managed the technology indigenization process only with foreign-enabling technologies until they could develop complex technology products themselves. Foreign-educated scientists and engineers have returned to higher education institutes and later industries (mostly chaebols). A few large private companies also tried to establish their own universities since1980s as university graduates failed to meet industry demands. POSTECH, founded by the Pohang Iron and Steel Company (POSCO), was one of the successes to build research-based university system through the commitment of repatriates from the US (Lee and Saxenian, 2013).

4. Promotion of National Research System Since 1990s

Promotion of university research and linkages of universities, industries and government research institutes were necessary as a few of Korean industries began to lead global markets such as semi-conductor, hand-phone and others. National R&D programs were expanded to have the Highly Advanced National Project (1992) and university research programs such as the Science Research Center (1992) and Engineering Research Center (1992) were inaugurated. National research management and evaluation system was introduced through the National Science and Technology Council (1991) and the Research Council System (1998) (Table4). Korea did not have to evaluate the government research programs in 1970s and 1980s since they were self-evident through government and private contract research in 1970s and complex technology products in 1980s. As universities were funded through national R&D programs, management and evaluation became inevitable for the first time in the Korean research program history.

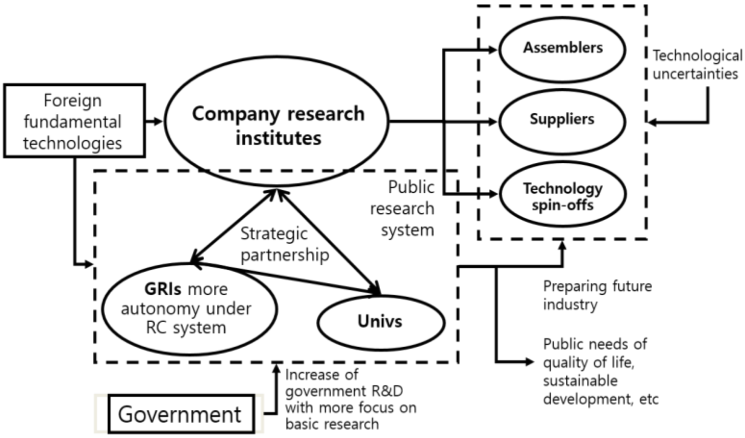
Table4 Framework conditions, goal and solutions in 1990s

	Descriptions
Framework Conditions	Economic development driven by innovation from investment-driven
Diagnosis-Based Goal	Promotion of university research and linkage of university-industry-government research institutes
Solutions	Expansion of National R&D programs through Highly Advanced National Project (1992) Creation of University R&D programs such as Science Research Center (1992), Engineering Research Center (1992), The Creative Research Initiative (1997), The National Research Laboratory (1999), etc Cultivation of Research Management and Evaluation System through National Science and Technology Council (1991) and Research Council System (1998)
Results	Increase of PhD graduates from 3,503 (1981) to 76,480 (2009), US patents from 236 (1981) to 23,584 (2008) and SCI articles from 17 (1981) to 7,548 (2008)

With expanded national R&D programs and university research programs, the number of PhD graduates increased from 3,503 (1981) to 76,480 (2009), US patents from 236 (1981) to 23,584 (2008) and SCI articles from 17 (1981) to 7,548 (2008). The Korean system has enlarged scientific foundation with which local strategic partnerships could be established.

With the enlarged capacity of local universities and GRIs, large companies have been enticed to build local strategic partnership and to leverage foreign technologies to acquire future industry development capacities in the uncertain technology market. And the public research system has also diversified research topics to address public needs for quality of life, sustainable development and others (Figure6). The government also began to increase basic research funding to further up the process, and technology start-ups have also grown since the Asian Financial Crisis in 1997 when spin-offs were triggered from public research system and the enlarged private research institutes.

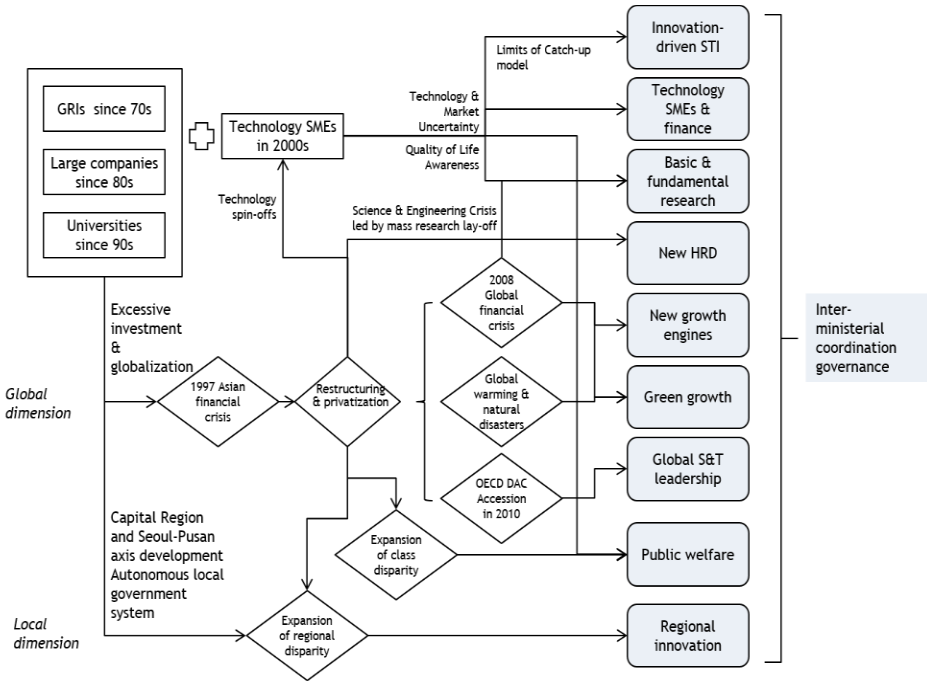
As the job market began to saturate with entrenched interests in Korea, foreign-educated scientists and engineers began to stay overseas after their graduation, by which diaspora networks especially in Silicon Valley began to grow and diversified (Lee and Saxenian, 2013). These networks need to be explored in the next phase of Korea's development.



Source: Lee and Saxenian (2013)

Figure 6 Cultivation of domestic strategic partnership

Throughout the Korean innovation system development, the STI issues were diversified, and inter-ministerial coordination governance became critical (Figure7). Beside the national STI issue of innovation-driven economic development, new growth engines and social issues such as quality of life, the harsh integration of the Korean system in the global system during the Asian financial crisis created technology startups as another important STI stakeholders. At the same time the massive layoff has facilitated the incorporation of new human resource strategies and people's welfare because of the expanded class disparity. This global dimension has intensified in Korea through the 2008 global financial turbulence and widened the responsibility toward global challenges after the accession to OECD Development Assistance Committee (DAC). The regional innovation has also emerged as an important STI issue in Korea since the mid-1990s when the country began to elect local mayors and governors.



Source: Lee (2011b)

Figure 7 Diversified STI issues and inter-ministerial coordination governance

5. STI Initiatives of Three Recent Korean Governments

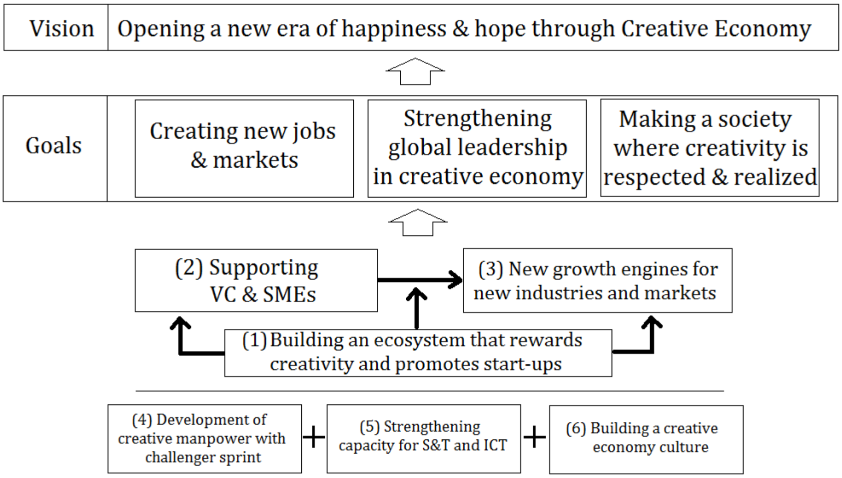
The following section reviews the three recent Korean governments' STI initiatives – green growth, creative economy and human-centered economy. The previous MB government proposed and implemented the green growth economy with three objectives and ten policy directions (Figure 8). The

Korean government identified new market opportunities to create new growth engines even with the global challenge of climate change. Technology development and relevant green industries were promoted during the green growth initiative.

Source: Government mimeo

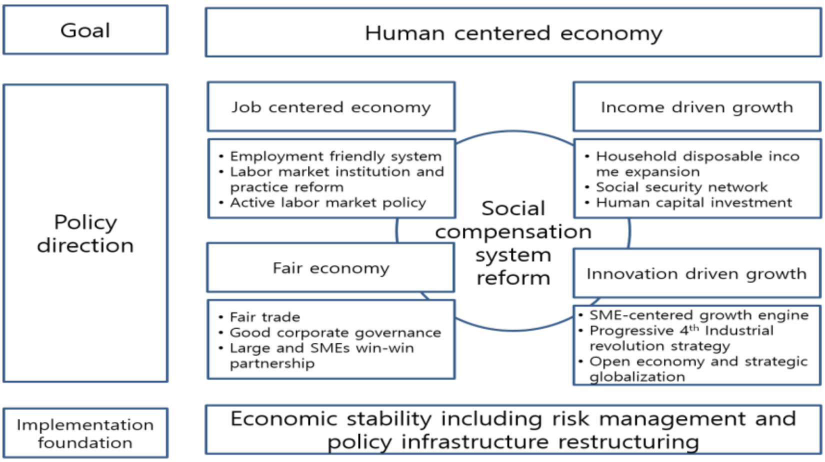
Figure 8 Green growth initiative

Similarly, the creative economy was conceptualized to actively create new qualified job opportunities with startup ecosystem development when the current industries do not provide them, which is a global phenomenon. Relevant programs were designed to facilitate the process (Figure 9). Among them, eighteen creative economy innovation centers led by large Korean companies, aligned with other innovation agencies and startup assistance programs, have provided new incubation space for new technology companies. Figure 10 summarizes the current government human-centered economy with income and innovation-driven growth and with institutional arrangements of job creation and fair economy.



Source: Government mimeo

Figure 9 Creative economy initiative



Source: Government mimeo

Figure 10 Human centered economy

6. Summary

The Korean system has consistently evolved from a nascent and fragmented assemblage to a strong and collective system through diagnosis-based targeting, relevant driving mechanisms with supporting policy schemes to coordinate domestic and international stakeholders, and coherent organizational and institutional arrangements. Also, structural capacities have been created for efficient and effective utilization of limited resources to trigger a virtuous circle of science and industry relations to continuously adapt the system in a changing global environment.

The targets were clearly identified in the structural bottlenecks and framework conditions of the Korean system –steel and iron in 1970s to steer the related heavy and chemical industries and semi-conductor to sustain electronics and to accommodate future technology industries in 1980s. The successful implementation of target sectors has continued to deepen and diversify Korean industries, which facilitated the system transformation in Korea. The three recent governments' initiatives can be said to be active approaches to address niche markets in the changing global environment while previous governments' approaches were passive to adapt to the global environment.

The driving mechanisms were designed to facilitate the coordinated implementation of STI stakeholders –the GRIs for technology acquisition and local dissemination since1970s, research consortia and promotion of private R&D investment for sharing uncertainties and build new technology industries since 1980s, research management and evaluation system to enlarge local innovation capacity and to induce the domestic strategic partnerships since 1990s.

Contract research schemes were comprehensively utilized for GRIs to work closely with private sectors in 1970s while a more complicated research management and evaluation system was introduced to manage the programs especially for universities in mid-1990s, and sophisticated inter-ministerial coordination governance became critical only in 2000s. The legal and macro-institutional framework was also coherently established such as macro-economic management and financial support and bank loan assistance for export promotion in 1960s, various laws, plans and programs in 1970s and 1980s.

The consistent, relevant and coherent system development has built Korea's systemic capacity to continuously accumulate capacities with which Korea could recover from the foreign-driven crises, created new industrial development capacities, and led global product and technology markets.

III. Principles and Methodologies for Diagnosis and Solution Articulation

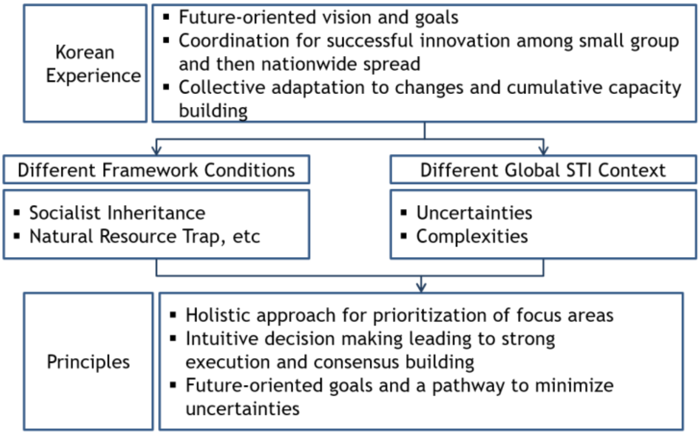
This chapter will articulate the STI strategy development principles with which methodologies will be further elaborated. As discussed in chapter one, the Korean experience cannot be appropriately benchmarked without contextual understanding, and only the principles can guide the relevant strategy development even in the different context and framework conditions.

1. Strategy Development Principles and Strategy Design Simulation Process

Korea has built a collective system with strong policy interventions with future-oriented vision and goals, coordination of successful innovation among small group stakeholders, and then nationwide spread. The system has enabled Korea to collectively adapt to foreign-driven crises and changes such as the 1997 Asian Financial Crisis and the 2008 global financial turbulence. As the Korean system recovered from the crises, capacities have been cumulatively built and the system became more competitive.

The Korean experience, therefore, has been benchmarked widely by a substantial number of governments. The public research institute system, national research consortium, technology extension and startup promotion have been used, but the results were not promising. They need to be redesigned to meet the different framework conditions such as socialist inheritance, natural resource traps among others. Also, the change of the global STI context makes it more difficult to benchmark Korea's experience. The technology life cycles are shortened dramatically and more stakeholders are engaged in the innovation process by which uncertainties and complexities increased.

A few countries such as Saudi Arabia hired an international consulting company to benchmark the Korean experience, which was not proven successful. They are mysterious to outsiders especially western consultants, policy makers and practitioners. It is almost impossible for them to understand since the decision-making criteria and processes are hidden. Other countries are trying to learn by way of setting co-working environment. Malaysia is pursuing "Look East Policy" of which the first phase focused on Japan. Malaysia is targeting Korea for benchmark at the second phase. That country wants to learn the Korean experience by setting a kind of ROK and ASEAN innovation center, which was proposed by the Prime Minister at the ASEAN-ROK Commemorative Summit in December 2014. It was incorporated in the Summit note, but not implemented.

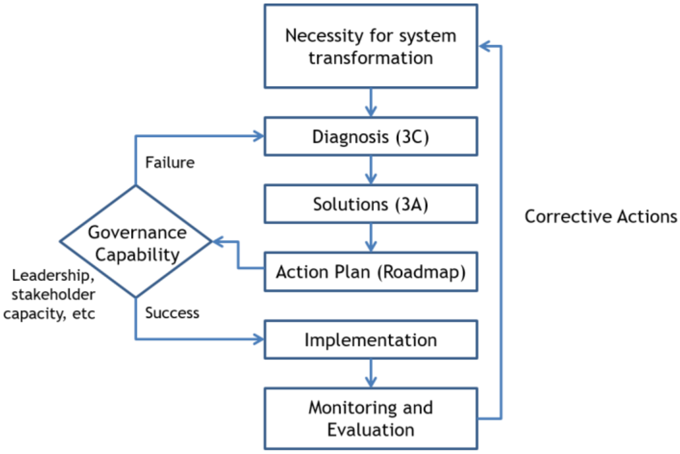


Source: Lee et al (2015)

Figure 11 STI Strategy development principles

Korea's experience needs to be conceptualized for western and other experts to understand. Figure 11 schematically describes the articulation process of three principles by which Korean STI decision-making, resource allocation and stakeholders engagement for implementation have been managed effectively. First, the focus or target areas were identified with a holistic approach. The targets are functioning as a system-transforming agent to change Korea to advance toward the next-generation development. Second, links to futuristic goals and pathways to achieve them were designed. As the resources and expertise were very limited, there should not be any chance of failure. The design process to achieve identified goals was to minimize uncertainties. Lastly, the path design process with programs and projects was intuitive in nature. The process was heuristic and plausible so that stakeholders could understand their roles in the program and they did not have to pay attention to what others were doing in the implementation process. This always led to strong execution and consensus building among implementing stakeholders with which Korea always achieved the goals before the plan was due.

Figure 12 describes the strategy design simulation process. It starts with the necessity for system transformation. The solutions are to be articulated after the system diagnosis and action plans with roadmap can be designed. Considering the governance capability, the action plans may go through the redesign process or they can be implemented. Corrective actions can be followed up with monitoring and evaluation. The three principles from the Korean experience will be the basis to develop methodologies for system diagnosis, solution articulation and further action planning process in the next section.



Source: Lee et al (2015)

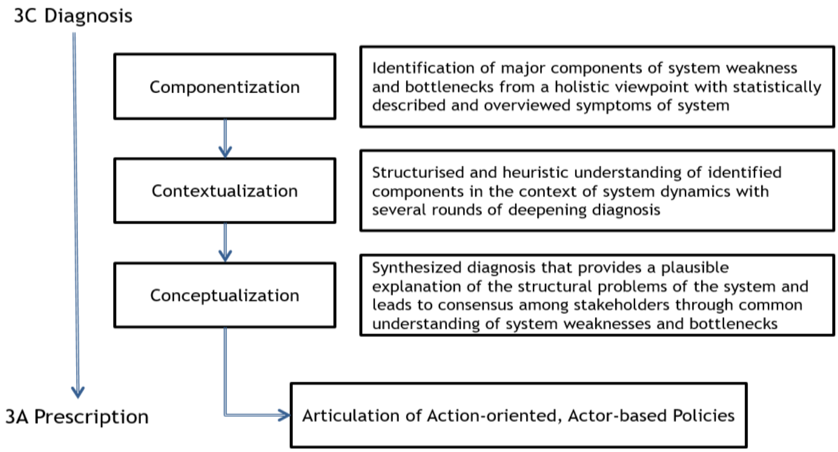
Figure 12 Strategy design simulation process

2. Diagnosis and Solution Articulation

The 3C diagnosis is conceptualized with the first principle of holistic targeting (Figure 13). The diagnostic process helps to reorganize overwhelming problems until it articulates action-oriented and actor-based policies (3A). The 3C diagnosis consists of three phases of componentization, contextualization and conceptualization. Major components of system weakness and bottlenecks are identified through the first step of componentization. In this step, the system is overseen from a holistic viewpoint with the support of a statistical description of the system and where relevant problems are integrated as components. Some are related to poor industrial capacities, another with unqualified human resources and education system, the other with bad innovation infrastructure while most of least developed and developing countries do not have experience and enough financial resources to address them.

In the next step, contextualization, the identified components are understood in structured and heuristic way with several rounds of deepening diagnosis in the context of system dynamics. The context of the problem components is different from country to country. For Laos, the rapid expansion of the tertiary education enrollment becomes a potential social problem since there are not enough quality jobs in the market. The challenge has increased from the dramatic decrease of infant mortality and hence natural increase of elementary school education with the support of the Millennium Development Goals (Lee, Maliphol and Kang, 2014). Thailand has a relatively good tertiary education system, but the industry and university linkages are deteriorated since industries are relying on foreign technology solutions and university graduates do not find relevant engineering jobs (Lee, Charoenchongsuk and Jutarosaga, 2017).

Lastly, the conceptualization process synthesizes the diagnosis results and provides plausible explanation for the structural problems of the system. The synthesized diagnosis leads to consensus among stakeholders on a common understanding of their system weaknesses and bottlenecks. They understand their problems in better ways and position theirs in the bigger context of the system bottlenecks. Existing policies can also be reviewed in the backdrop of the synthesized diagnosis and this helps why current policies are not implemented and, if implemented, do not solve the problems and sometimes intensify them.

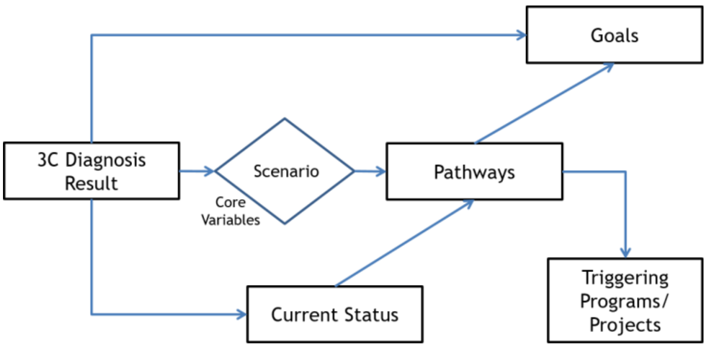


Source: Lee et al (2015)

Figure 13 3C diagnosis and 3A solutions for targeting

In a similar way of diagnosis, alternative solutions can be articulated with the synthesized diagnosis. With limited resources and expertise, the leverage points are conceptualized where success can facilitate the chain-linking effects to transform the whole system until it can create a certain virtuous cycle. The technology platform for quality assurance and capacity building was proposed as a solution as Tanzania is challenged with at least three structural bottlenecks – substandard drugs and endemic disease, budget deficit and limited quality assurance, and low innovation trap in an oligopolistic market (Lee, Maliphol, Sun, Yang and Dong, 2013). The alternative solutions from the diagnosis entail two action plan components about who needs to do what and in what successive way. This is why the alternative solutions are named as 3A (Articulation of Action-oriented and Actor-based policies) prescriptions.

The relevant programs and projects are designed from the system pathway through which the current status of vicious cycle can be transformed until it achieves the future goals (Figure 14). The diagnosis not only elaborates the current status, but also incorporates the future goals. Disease eradication through sustainable pharmaceutical production for export was conceptualized as a future goal for Tanzanian pharmaceutical innovation strategies (Lee, Maliphol, Sun, Yang and Dong, 2013). And the conceptualized future goals can further guide the strategic scenario in the pathways, which is developed with the alternative solutions. This is related to the second principle of futuristic goals and pathways.



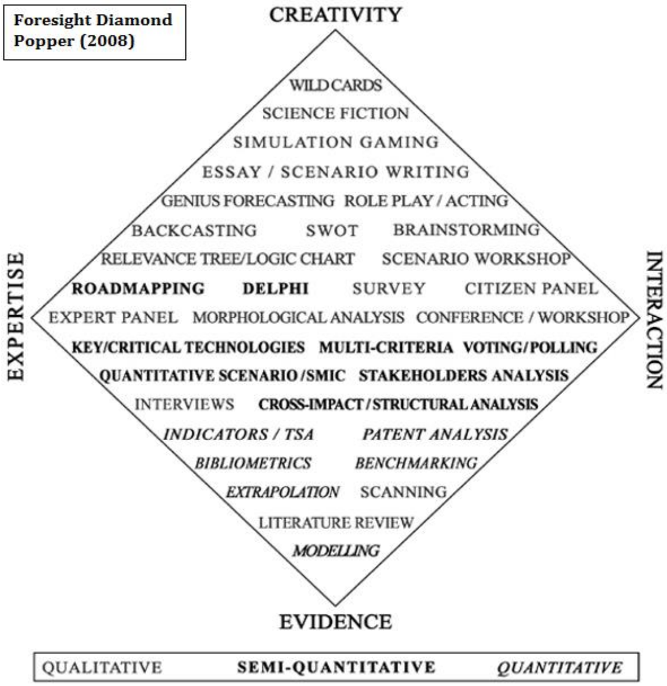
Source: Lee et al (2015)

Figure 14 Futuristic vision and scenario-based solutions

3. Relevant and Appropriate Intuitive Approach

Popper's foresight diamond includes various methodologies (Figure 15). As the STI strategies are designed, how many methodologies need to be utilized? If we do not have planning infrastructure of statistics, indicators and benchmarking cases, how can we manage to develop strategies? In reality, we are asked to submit strategies to decision makers in a few months and we are not given enough financial resources to manage it. What might be guidelines for data collection and analysis until relevant policies and strategies are designed. These kinds of questions are more critical when they are developed in least developed and developing countries since most of them do not have planning infrastructure, experience and resources to produce them in the near future.

An appropriate methodology for effective planning with limited resources and time needs to be considered. A kind of expert panel brainstorming is recommended. A few rounds of panel discussions can be managed with experts from industry, university, research institute and government with a stake in the areas of strategy development, and they can share their experience and ideas to address the challenges. The third principle of intuitive decision-making is aligned with the heuristic and plausible scenarios development approaches. Participants' experiences and ideas are shared and elaborated as strategies through which participating stakeholders can contribute to the strategy development and to position themselves in the future implementation process.



Source: Popper (2008), recited from Lee et al (2015)

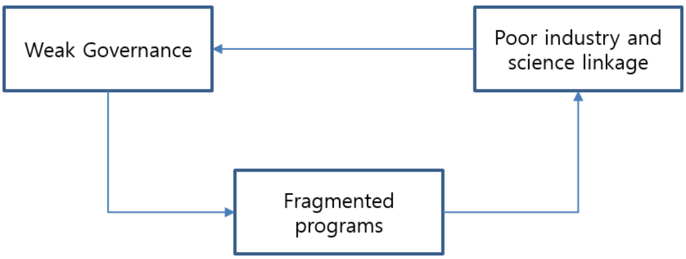
Figure 15 Foresight diamond

IV. Roadmap and Action Planning Guides for Developing Countries

Most of advanced countries have quite a good deal of previous experience in innovation program design and implementation. Then, their strategy cycle, where roadmap and program are the steering components, normally starts with the auditing and benchmarking. The regional strategies and innovation of Baden-Wurttemberg, Germany, which is led by the Steinbeis-Europa-Zentrum, are managed as follows (Clar, 2018a, b);

- Identifying and assessing current strengths and future development potential (auditing)
- Benchmarking against current and potential competitors
- Understanding relevant global developments and emerging global value chains, with the aim to optimally position regional strengths and potential, and to develop future options (foresight) and to assess them (ex-ante impact assessment)
- Prioritizing options and concretizing them (roadmapping) and focusing resources, detailing actions, looking for partners and others (strategic program design)
- Monitoring program implementation

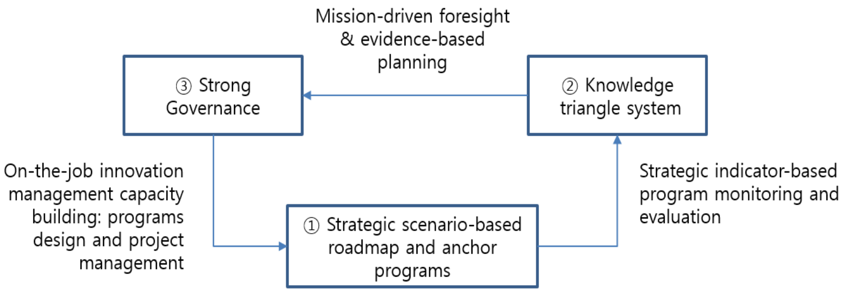
It is almost impossible for least developed and developing countries to build a strategy cycle in a few years since there is a vicious cycle of innovation program design and implementation (Figure 16). Most of them have weak governance in innovation management since they do not have an industrial promotion experience. If they do, they used to rely on regulation changes and infrastructure development for the industrial promotion and economic development, especially with the strategic inducement of foreign direct investment. Thailand is a typical case. The country recognized the importance of technology development and began to increase government R&D programs.



Note: Author's rendering

Figure 16 Vicious strategy cycle

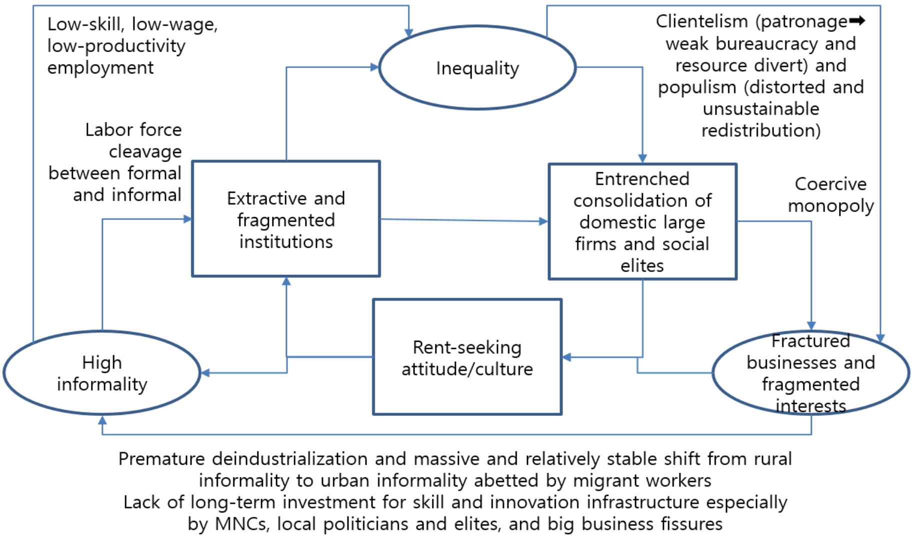
Thai innovation programs, however, are fragmented as the locally-developed technologies are not utilized by private stakeholders, and human resources from universities cannot easily find relevant and qualified jobs in the market. Then, the industry and science linkages are not cultivated in the country. The strategy cycle cannot start with empowering the governance, but the strategic scenario-based anchor programs and roadmap should be targeted (Figure 17). The program will create a few demonstrable cases of knowledge triangle system in their countries where private companies utilize locally-developed technologies, and students can find jobs in the relevant public and private organizations. On-the-job innovation management capacity-building for program design and project management needs to be properly arranged. While a few anchor programs are implemented with the roadmap, strategic indicator-based monitoring and evaluation can be designed. This process will enable a strong governance-building mechanism even in the least developed and developing countries. Mission-driven foresight and evidence-based planning can be institutionalized to create a virtuous strategy cycle in the country.



Note: Author's rendering

Figure 17 Proposed strategic cycle

The roadmap can be incorporated from the synthetic diagnosis and strategic solutions. As for Tanzanian pharmaceutical innovation, the proposed technology platform for quality assurance and capacity building will steer quality-assured drug deployment, incentivize infrastructure investment, break off the low innovation trap, deter the continuity of political collusion in the drug market and then supply quality drugs in Tanzania (Lee, Maliphol, Sun, Yang and Dong, 2013). The roadmap can inform stakeholders about key steps and their roles in the pathway to achieve the envisioned goals. Similarly, relevant programs and projects can be designed to implement the strategic solutions with the roadmap. If strategic scenario and roadmap are not considered, most programs will be just supply-push style infrastructure and technology development projects, which will not have impact for the country. STI infrastructure and strategic human resource development programs were proposed to address the endemic poverty in Laos with the twin engines for green growth to promote target industries of green vehicle, tourism and agro-food (Lee, Maliphol, and Kang, 2014).



Note: Author's rendering based on Doner and Schneider (2016)

Figure 18 Innovation governance issues

Lastly, innovation governance needs to be proposed. Figure 18 elaborates the complex issues of innovation governance in least developed and developing countries. Doner and Schneider (2016) have analyzed the case of Thailand to address the middle-income trap. There is a vicious circle of entrenched consolidation of domestic large firms and social elites, rent-seeking attitude and culture, and extracted and fragmented institution. The vicious circle has intensified through fractured businesses and their fragmented interests, high informality and inequality. Clientelism and populism, coercive monopoly, shift of rural informality to urban informality in the premature de-industrialization, lack of long-term capacity development, and labor cleavage with low skill, wage and productivity are symptoms of low innovation and middle income trap.

The innovation governance shall consider the structural bottlenecks in the country, and the governing mechanism shall also provide the autonomy and sustainability of the implementing bodies for strategic alliance and scale up implementation. Ownership of funding by which resources are timely allocated in the targeted areas is also important for an efficient and effective implementation.

V. Conclusion

The Korean STI development experience is widely acknowledged as a benchmarking case not only for developing, but also for developed countries. This article has sought to go beyond simply describing and sharing successful cases in Korea, which Dr. Choi (1988) humbly expressed in his memoirs, but it articulated the STI strategy development principles and methodologies.

This has been elaborated through iterative processes of bi- and multilateral STI strategy development cases for the last ten years. The principles were originally conceptualized from the benchmarking process of Korea's STI development experience and further incorporated as methodologies with which relevant planning bodies are guided to address individual and regional challenges by science, technology and innovation strategies.

The methodologies are strong in providing plausible scenario in a holistic perspective by which various stakeholders can be engaged in the planning and implementation process. But it is heuristic in nature and can be learned only through on-the-job training process. This is the structural limitation for scaling up, which is different from the scientific analysis-based approach.

The iterative elaboration process has continued with consultation activities for Thailand since July 2016 and for Cambodia, Laos and Myanmar in planning partnership with Thailand. Various sectoral, local, regional and national issues have been, and will be reviewed to further develop diagnosis and solution articulation methodologies.

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