BACKGROUND PAPER

# Innovation Policy in Asia

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# INNOVATION POLICY IN ASIA

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February 2020

## CONTENTS

Page

## I. INNOVATION POLICY: NECESSITY, DEFINITION, INSTRUMENTS, AND GOVERNANCE

This chapter describes why innovation policies are needed, what they are, and how they are implemented. As part of public policy and broader than technology policies, innovation policies are necessary to overcome market, capability, and system failures. Innovation policies can be classified into three according to their orientation, namely, mission, invention, and system orientation. Innovation policy has various instruments, and the goals and effects of each instrument vary in each country.

### A. Necessity of Innovation Policies

What are the theoretical rationales behind innovation policy? Some innovation policies, such as those supporting the research and development (R&D) of military technology, have been pursued for centuries (Bloom, Reenen, & Williams, 2019). For example, Defense Advanced Research Projects Agency (DARPA) in the United States (US) focuses on finding ways to leverage new knowledge gained from research. Jet engines, radar, nuclear power, GPS, and Internet technologies have been originally initiated, funded, or even developed by military research projects. Investing in creating and diffusing knowledge beyond military purposes is important. Farming methods are typical examples. The modern state has always supported the generation of scientific knowledge, technology, and innovation, as part of its core policy missions.

The implication is that these policies emerged before the birth of modern social sciences and economics. Thus, elaborate theoretical constructs that justify these policies came later and can generally be seen as ex-post rationalizations of already existing practices. However, these constructs are not necessarily useless. They provide legitimation (which is always important for policy), help shed light on why and how a policy works (or not), and underpin the designing, implementation, and revision of policies. The need for an innovation policy can be summarized in three manners (Table 1).

The following reasons underscore the necessity for innovation policy. The first reason is market failure. Innovation is difficult to create, and monetizing it is even more difficult. Nevertheless, innovation spread quickly among markets and are easy to imitate. Therefore, innovators can find recovering these costs difficult despite considerable money invested in R&D. In today's knowledge-based economy, unintended knowledge spillover is increasingly strengthening market failure. For example, pharmaceutical firms invest billions of dollars in developing new drugs; however, generic drugs are often introduced easily. Thus, governments use various methods to protect innovators' economic rents through policies, such as patent protection and intellectual property rights.

The second reason is system failure. From the path-dependent characteristic of technology trajectory, innovation processes follow the danger of lock-in to existing technologies. Thus, technology is developed depending on previous patterns or paths (e.g., R&D strategies and institutions) when successful results have been made in the past. Firms and governments tend to stick to existing technology development strategies or policies due to sunk cost. After all, in a situation of high uncertainty, finding something new from an existing system of relatively high stability is difficult because firms do not know the best way to solve the problems it faces. Finally, the performance of technological innovation is adversely affected (Antonelli, 1997). External actors that can generate incentive, develop technological alternatives, and nurture emerging technological systems are often required (Ediquist, 1999). For example, public procurement in France maintains technological diversity by supporting two systems and thus provide France with the capability to alternate between them (Ediquist, 1998).

The third reason is capability failure (Lee, 2013). Innovation systems are necessary for national innovation. However, the innovation system of developed countries is indirectly applicable to developing countries (Viotti, 2002), although the strategy for building the system is needed (Arocena & Sutz, 2000) because developing countries often lack the capability to adopt the developed countries' innovation system. For example,

firms in developing countries with low R&D capabilities buy or borrow external technologies to minimize risk (Lee, 2013). The government needs a way to cultivate R&D capabilities in various ways, such as R&D funds. For example, the Republic of Korea (ROK), in developing phase, has established and actively supported various research institutes (e.g., Korea Institute of Science and Technology (KIST), Korea Advanced Institute of Science and Technology (KAIST), Electronics and Telecommunications Research Institute (ETRI), and Korea Development Institute (KDI)) to overcome the lack of technological capabilities. Moreover, the Government of the ROK supports *chaebols* directly and indirectly, helping them gain various project execution capabilities.

**Table 1: Three Types of Failure**

| Classification | Market Failure | System Failure | Capability Failure |
|---|---|---|---|
| Focus | Market institution | Interaction among actors | Actors (firms) |
| Source | Knowledge as public good | Cognition failure from tacit 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 |
| Relevance | Developing and advanced countries | Developing and advanced countries | More unique to developing countries |

Source: Adapted from Lee (2013).

**B. Definition of Innovation Policy**

Innovation can be defined as the result of a "new combination" of knowledge, capabilities, and resources (Schumpeter, 1934). Different from invention, which is defined as "a novel idea for how to do things," innovation is a concept that includes what is "carrying it out into practice." This perspective has something in common that creates something new; however, it differs whether new ideas are realized economically and socially. Innovation also includes product and process innovations. Therefore, innovation research has been linked to science and technology (S&T), with emphasis on institutions that discipline innovative activities and on "co-evolution of technologies and institutions" that require new systems that conform to new technologies (Nelson & Sampat, 2001).

Innovation policies have been defined in various ways by different times and different motivations. Some of these policies may relate to terminological shifts (Boekholt, 2010). For example, much of what is called innovation policy today may previously have been labeled as industrial, science, research, or technology policy. In this respect, innovation policies are broader concepts than existing technology policies, which are defined as "policies involving government intervention in the economy with the intent of affecting the process of technological innovation (Stoneman, 1987)." Innovation policy must consider innovation as a broad and holistic perspective beyond invention (Edler & Fagerberg, 2013). In addition to economic goals, it seeks to integrate S&T with the emergence of new policy goals, such as improvement of quality of life, enhancement of sustainability, and social integration (Geels, 2004).

Thus, innovation policies can be divided into three, namely, mission-, invention-, and system-oriented policies (Edler & Fagerberg, 2013).

**Mission-oriented policies** can be described as big science that provides solutions to practical and specific social problems (Ergas, 1986). The dominant feature of these policies is concentration. Policymakers focus on few technologies, such as aerospace, electronics, and nuclear energy. Moreover, policymakers have

adopted such policies long before innovation policy, for example, for defense purposes. Many important innovations with great economic effect have resulted from such policies (Mowery, 2011; Mazzucato, 2013).

**Invention-oriented policies** have a narrow focus and concentrate on the earlier phase, especially R&D and invention. Societal and economic effect through diffusion and exploitation leave to the market (Edler & Fagerberg, 2013). The underlying assumption of these policies is that technologies might have potential benefits for society as a whole. In the post-Second War period until the 1960s, policymakers with these assumptions led to the creation of new public organizations, such as research councils. Invention-oriented policies were usually considered part of R&D research or science policies; however, they are often simply classified as innovation policies today (Edler & Fagerberg, 2013)

**System-oriented policies** have been focused on recently. Such policies originate from the national innovation system (NIS). The concept of NIS became broadly diffused through the 1980s. Lundvall (1992) defined NIS as "the elements and relationships which interact in the production, diffusion, and use of new and economically useful, knowledge... and are either located within or rooted inside the borders of a nation state." System-oriented policies focus on the degree of interaction among different parts of the system, the component of which requires improvement or where the actors should participate. The Organization for Economic Cooperation and Development (OECD) adopts system-oriented policy advices and evaluations.

NISs can be broadly categorized into liberal market economies (e.g., the United Kingdom and the US) and coordinated market economies (e.g., Germany and Japan). Each type has a different way of creating innovation. Liberal market economy is suitable for radical innovation based on scientific knowledge and requires flexibility in funding. By contrast, coordinated market economies are suited for incremental innovation based on accumulated know-how in the field and long-term relations with the internal labor market (Coriat & Weinstein, 2004).

## C. Innovation Policy Instruments

### 1. Taxonomy of Innovation Policy Instruments

Before discussing innovation policy instruments, public policy instrument must be defined. Public policy instrument is "a set of techniques by which governmental authorities wield their power in attempting to ensure support and effect (or prevent) social change (Vedung, 1998)." As the definition implies, public policy instrument has a clear purpose, and so does innovation policy instrument, which is to stimulate innovation (Borras & Edquist, 2013).

Public policy instruments can be identified in various ways, namely, (1) regulatory instruments, (2) economic and financial instruments, and (3) soft instruments (Borras & Edquist, 2013).

The first type, regulatory instruments, use legal tools for the regulation of social and market interactions. The most representative innovation policy instruments are intellectual property rights. Intellectual property is a concept that includes patents, copyrights, and trademarks. The conditions for registering a patent are novel, non-obvious, useful, and satisfy public disclosure requirement. However, business method, medical diagnostic test, human genes, and software program do not satisfy these conditions. Such nonpatentable technologies or inventions have social benefits. A debate also exists over the risk of patent trolls collecting patents and generating revenue without technology development; however, finding evidence that patent trolls degrade the well-being of society as a whole is difficult (Karakashian, 2015).

The second type, economic and financial instruments, provide specific pecuniary incentives (or dis-incentives) and support. Typical instruments include fiscal incentives for R&D, such as tax exemptions. Whether tax credits are effective in increasing corporate R&D spending has been validated by various studies. According to the OECD (2018) report, 32 of the 42 countries provide tax generosity in R&D. A concern regarding tax

credits is that firms turn simple spending into R&D expenditure to reduce taxes. In the People's Republic of China (PRC), as well as the US and the United Kingdom, this phenomenon has been studied in recent research (Chen et al., 2019; Lucking, 2019; Akcigit et al., 2018). Another example is government research grants. Government research grants support knowledge creation and spillover, which is difficult for private firms to do. Particularly, innovative products in the US are often developed through research funds, such as DARPA and National Institutes of Health (NIH), and spillover through Small Business Innovation Research (SBIR). These research grants may be given directly to companies but most often go to universities or research institutions. The knowledge spillover from the university to the private sector is another matter of debate. However, many universities have a technology transfer department that attempts to transfer knowledge to the private sector.

The third type, soft instruments, have no direct government involvement, but appeal or offer voluntary contractual agreements. This type of public policy instruments attracts various governments. Soft instruments change the role of the government from providers or regulators to coordinators or facilitators. Human capital supply can be an example of soft instruments. Investing in universities is a common way to increase the human capital supply; however, soft instruments come in various forms. One of the instruments encourages highly educated people to immigrate. Another approach is lowering barriers for talented people to become inventors, including the promotion of women's scientific workforce and discrimination against the minority.

**Table 2: Examples of Innovation Policy Instruments**

| Category | | Examples of instruments |
|---|---|---|
| Regulations | Use legal tools for the regulation of social and market interactions | - Intellectual property rights<br>- Competition law<br>- Ethical regulation |
| Economic transfers | Provide specific pecuniary incentive (or disincentives) and support | - Tax exemptions<br>- Research grants to universities and research institutes<br>- Competitive research funding<br>- Support to venture and seed capital<br>- Public procurement for innovation |
| Soft instruments | Change the role of the government from providers or regulators to coordinators or facilitators | - Voluntary standardization<br>- Codes of conduct<br>- Public–private partnership (PPP)<br>- Voluntary agreements |

Source: Adapted from Borras and Edquist (2013, p. 1,517).

Edler and Fagerberg (2017) suggested a typology based on a comprehensive synthesis of existing evidence on innovation policy instruments. Table 3 shows the typology of instruments focusing on supply of or the demand for innovation. It also considers a range of innovation policy goals and shows how the various innovation policy instruments relate to these goals.

**Table 3: Taxonomy of Innovation Policy Instruments**

| | | Overall Orientation | | Goals | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Innovation Policy Instruments | Supply | Demand | Increase R&D | Skills | Access to Expertise | Improve Systematic Capability, Complementarity | Enhance Demand for Innovation | Improve Frame work | Improve Discourse |
| 1 | Fiscal incentives for R&D | ●●● | | ●●● | ●○○ | | | | | |
| 2 | Direct support to firm R&D and innovation | ●●● | | ●●● | | | | | | |

| | | Overall Orientation | | Goals | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Innovation Policy Instruments | Supply | Demand | Increase R&D | Skills | Access to Expertise | Improve Systematic Capability, Complementarity | Enhance Demand for Innovation | Improve Framework | Improve Discourse |
| 3 | Policies for training and skills | ●●● | | | ●●● | | | | | |
| 4 | Entrepreneurship policy | ●●● | | | | ●●● | | | | |
| 5 | Technical services and advice | ●●● | | | | ●●● | | | | |
| 6 | Cluster policy | ●●● | | | | | ●●● | | | |
| 7 | Policies to support collaboration | ●●● | | ●○○ | | ●○○ | ●●● | | | |
| 8 | Innovation network policies | ●●● | | | | | ●●● | | | |
| 9 | Private demand for innovation | | ●●● | | | | | ●●● | | |
| 10 | Public procurement policies | | ●●● | ●●○ | | | | ●●● | | |
| 11 | Pre-commercial procurement | ●○○ | ●●● | ●●○ | | | | ●●● | | |
| 12 | Innovation inducement prizes | ●●○ | ●●● | ●●○ | | | | ●●○ | | |
| 13 | Standards | ●●○ | ●●○ | | | | | ●●○ | ●●● | |
| 14 | Regulation | ●●○ | ●●○ | | | | | ●●○ | ●●● | |
| 15 | Technology foresight | ●●○ | ●●○ | | | | | | | ●●● |

Notes: ●●●=major relevance, ●●=moderate relevance, and ●=minor relevance to the overall orientation and stated innovation policy goals of the listed innovation policy instruments.
Source: Adapted from Edler et al. (2016, p. 11).

## 2. Effect of Innovation Policy Instruments

From the perspective of policymakers, measuring the effectiveness of policy instruments is of great concern. Numerous attempts have been done to evaluate the effect of innovation policy intervention (Edler et al., 2012; Molas-Gallart & Davies, 2006; Papaconstantinou & Polt, 1997). However, these attempts are difficult to achieve. Similar to other policy interventions, direct effects are easy to measure; however, indirect effects, such as productivity increase and job creation, are difficult to measure (Edler & Fagerberg, 2017). Furthermore, distinguishing the effect of individual innovation is challenging because innovation policy instruments depend on the innovation system.

First, although immediate effects, such as whether R&D support leads to more R&D performance may be easy to assess, wider effects on innovation, productivity, and jobs, which are presumably what policymakers are interested in, are considerably more challenging to assess. This situation has to do partly with the fact that innovation is notoriously difficult to measure, and partly because long lags often exist between innovation and its social and economic effect.

Second, different policy instruments may interact, which makes distinguishing their individual effects difficult. Moreover, the effect of any innovation policy instrument depends on the working of the wider innovation system into which it is sought to be introduced. This condition raises serious questions regarding the usefulness of evaluations of individual policy instruments and leads to a call for systemic evaluations (Smits & Kuhlmann, 2004).

Third, differences in context are important, and even identically named policy instruments of the same design lead to dissimilar outcomes in different countries at different times (Edler et al., 2016). The present study identified numerous variables influencing the effects of innovation policy instruments, such as interaction with other interventions (which policymakers are often unaware of), conditions for implementation, local and national capabilities, economic structure, profile and performance of the national science base, development of financial markets, and cultural factors (e.g., attitudes toward openness, interaction, risk taking, and experimentation).

Bloom et al. (2019) summarized the existing literature considering the effects of innovation policies on time frame and inequality (Table 4).

**Table 4: Effects of Innovation Policy Instruments**

| **Policies** | **Quality of Evidence (1)** | **Conclusivenes s of Evidence (2)** | **Net Benefit (3)** | **Time Frame (4)** | **Effect on Inequalit y (5)** |
|---|---|---|---|---|---|
| Direct R&D grants | Medium | Medium | ●● | Medium run | ↑ |
| R&D tax credits | High | High | ●●● | Short rum | ↑ |
| Patent box | Medium | Medium | Negative | NA | ↑ |
| Skilled immigration | High | High | ●●● | Short to medium run | ↓ |
| Universities: incentives | Medium | Low | ● | Medium run | ↑ |
| Universities: STEM supply | Medium | Medium | ●● | Log run | ↓ |
| Trade and competition | High | Medium | ●●● | Medium run | ↑ |
| Intellectual property reform | Medium | Low | Unknown | Medium run | Unknown |
| Mission-oriented policies | Low | Low | ● | Medium run | ↑ |

Notes: This table is a highly subjective reading of the evidence. Column 1 reflects a mixture of the number of studies and the quality of the research design. Column 2 indicates whether the existing evidence delivers any firm policy conclusions. Column 3 is our assessment of the magnitude of the benefits minus the costs (assuming these are positive). Column 4 delineates whether the main benefits (if any) are likely to be seen in the short run (approximately the next three to four years) or in the longer run (approximately ten years or more); NA means not applicable. Column 5 lists the likely effect on inequality.

Source: Adapted from Bloom et al. (2019, p. 180).

### D. Innovation Policy Governance

Innovation governance is the power to make decisions about aligning goals and distributing resources in creating innovation. As previously discussed, innovation is a concept larger than invention, which refers to real changes that have socioeconomic effects and requires the participation of various actors. Although the form of innovation governance is sometimes convergent, the actual operation of the system slightly differs depending on the inherent institutional heritage of the country and the contextual situation that faces the society (Boekholt et al., 2002; Arnold et al., 2003).

Two trends are observed in innovation policy governance. First, specialized public sector organizations dedicated to innovation support have emerged in many countries (Edler & Fagerberg, 2013). One study identified about 50 "national innovation foundations" (Ezell et al., 2015). These institutions [e.g., Finnish Fund for Independence (Suomen itsenäisyyden juhlarahasto) and US's DARPA] have been emerging in developed and developing countries. A study of a selected number of such agencies identified considerable differences in their structures and priorities (Glennie and Bound, 2016), which reflect the characteristics of the national systems to which they belong to some extent.

The second tendency is the increasing involvement of different ministries, which are not limited to those related to S&T. In addition to ministries, various levels of institutions (e.g., local governments, NGOs, trade associations, and industry associations) are involved in innovation policy because innovation must address various challenges, such as climate change, energy, and health.

Innovation policy governance is arguably important for the design and implementation of effective innovation policies. However, it is an under-researched topic. Thus, studies benefitting from an interdisciplinary perspective (including political science/public administration) are needed.

## II. OVERVIEW OF INNOVATION POLICY: EIGHT ASIAN COUNTRIES

This chapter reviews the innovation policy of eight Asian countries over time. Eight countries are selected considering income level[1] and market size. These countries are grouped into four: 1) high-income countries (i.e., Japan and the ROK), 2) big-market countries (i.e., the PRC and India), 3) middle and upper-middle income countries (i.e., Indonesia, Thailand, and Malaysia), and 4) low-income countries (i.e., Bangladesh).

### A. Japan

#### 1. Performance of Innovation Policies

Japan, the first Asian country to succeed in industrialization and catch up to advanced countries, has the world's third largest economy in terms of nominal GDP and ranks fifth in the 2018 Global Competitiveness Index (WEF, 2018). Japan is one of the largest investors in science, technology, and innovation (STI) by R&D expenditure. According to the National Science Foundation, Japan ranks fourth after the US, the PRC, and the EU when comparing R&D investment in each country as of 2015. Among the total R&D spending, domestic private investments, including business enterprises and nonprofit organizations, accounted for 79.1% in 2017. According to the Ministry of Education and Science of Japan, the share of Japan in the number of papers in 2014 is less than 5% (three-year moving average), which is three to four times lower than that of the US and the PRC [15%–20% (KIAT, 2018)].

**Table 5: Chronological Changes in the Performance of Japanese Innovation Policy**

| Classification | | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Economic growth | GDP (billion US$) | 44 | 213 | 1,105 | 3,133 | 4,888 | 5,700 | 4,971 (3rd) |
| | GDP per capita (US$) | 479 | 2,038 | 9,465 | 25,359 | 38,532 | 44,508 | 39,287 (24th) |
| | GNI per capita (US$) | 610 (in 1962) | 1,830 | 10,860 | 27,810 | 36,230 | 43,440 | 41,340 (17th) |
| Innovation input | R&D expenditure (% of GDP) | n/a | n/a | n/a | 2.7 (in 1996) | 2.9 | 3.1 | 3.2 (in 2017) |
| | R&D expenditure (public vs. private) | n/a | n/a | n/a | n/a | 22:78 (in 2006) | 23:77 | 20:79 (in 2017) |
| | Researchers in R&D (per million people) | n/a | n/a | n/a | 4,874 (in 1996) | 5,078 | 5,103 | 5,305 (in 2017) |
| | Technicians in R&D (per million people) | n/a | n/a | n/a | 662 (in 1996) | 619 | 582 | 521 (in 2017) |
| Innovation output | High-technology exports (% of | n/a | n/a | 23.9 (in 1988) | 24.2 | 28.7 | 19.2 | 17.3 |

[1] The income level refers to the 2018–2019 thresholds for income classification suggested by the World Bank. The threshold by income level is as follows: low-income is below 996; lower-middle income is 996–3,895; upper-middle income is 3,896–12,055; and high-income is above 12,055 GNI per capita (US$).

| Classification | | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|---|
| | manufactured exports) | | | | | | | |
| | Patent applications, residents | n/a | n/a | 165,730 | 332,952 | 384,201 | 290,081 | 260,290 (in 2017) |
| | Patent applications, nonresidents | n/a | n/a | 25,290 | 27,752 | 35,342 | 54,517 | 58,189 (in 2017) |
| | No. of scientific and technical publications | n/a | n/a | n/a | n/a | 97,235 (in 2003) | 108,292 | 96,536 (in 2016) |

Source: Authors' creation based on the database provided by World Bank and Eurostat Data.

## 2. Evolution of Innovation Policies

Japan has been developing its innovation policies since the late 1800s and is now experiencing a paradigm shift of innovation policies and various social and environmental problems. Its early innovation policies focused on expanding access to international knowledge and accumulating indigenous human capital. By assembling appropriate governance structures that promoted strong linkages among selected industries, government institutions, and academia, Japan succeeded in securing firm innovation capabilities afterward. Its strategic industries changed from heavy industries to electronics and life sciences, which is consistent with its timely economic structure shift and rapid economic catch-up. In the post catch-up stage to the present, Japan emphasizes supporting sustainable and inclusive growth, which responds to severe social and environmental issues (e.g., aging population, pollution, and natural disasters).

### a. Pre-industrialization phase (1868–1888): Meiji Restoration period

Japan was among the earliest empires that have absorbed and accumulated scientific knowledge and technological capabilities since the late 1800s. In this period, a wide-ranging transformation occurred, ranging from the dismantling of the Shogunate (government) to the establishment of central unified power through the restoration of the monarchy. The Meiji government sought reform to catch up with the Western powers. While promoting a series of reforms (e.g., school systems, conscription, and tax reform), the government attempted to foster capitalism and strengthen the military under the leadership of the emperor, modeled after the modern countries of Europe and the US. Japan's modernizing logic of introducing Western technology and systems based on Japan's traditional spirit (和魂洋材論) was established during this time. The government gave preferential treatment to foreign engineers, and government-sponsored import policies started the acquisition of light industry technologies, such as textiles.

### b. Industrialization and catch-up phase (1889–1970s)

**Early industrialization phase (1889–1945)**

Many scholars believe that the Meiji Restoration ended with the enactment of the Japanese Imperial Constitution in 1889. The growth of the heavy industries (i.e., iron and steel) was boosted in subsequent wars, such as the First Sino–Japanese War (1884–1885) and the Russo–Japanese War (1904–1905); the relevant technological capabilities were successfully accumulated in the 1920s and 1930s. In all these events, governments played a major role in building indigenous manufacturing capabilities and fostering technology diffusion. Initially, the explicit policy goal was to spread foreign equipment imports, spread the technology to the private sector, and play an important role in accumulating technological capabilities in selected sectors. For example, during the First World War, the focus was on fostering the automotive industry, and the Navy aimed

to acquire shipbuilding technological capabilities. Furthermore, government-supported institutions were established to manage and supervise Japan's scientific and technological activities. Japan also spared no support for technology transfer programs and S&T education and actively sent government officials and students to Europe. Between 1887 and 1938, the average growth rate of manufacturing industries was more than quadruple the 1.36% of agriculture (Macpherson, 1995).

**Late industrialization phase, after the Second World War (1946–1959)**

During the Second World War, Japan's economy and industry suffered huge losses, and over a third of industrial machinery was destroyed. The main goal of the post-war innovation policy was to promote industrial recovery and economic growth. The choice of specific areas of technology pursued in the 1960s and 1970s was sometimes determined by social needs, such as finding solutions to pollution, traffic congestion, and water shortage. At this time, Japan's greatest strategic goal was to close the technological and economic gap with the US.

After the Second World War, modern technology for industrial development was imported from developed countries. Approximately 80% of imported technology was associated with mechanical and chemical industries. As a result, industrial production in the late 1950s grew more than 20% annually, and the electronics and automotive industries became globally successful. Japanese companies also innovated and improved their imported technologies to develop several new products. For example, Sony emerged as a global leader in the consumer electronics industry with the launch of several new devices worldwide, such as portable electronic music player called Walkman and videotape recorders.

Notably, indigenous technology improvements were led by private companies investing in R&D. Although several technological advances were made through Japan's own technology development efforts, industrial laboratories focused on improving existing or imported technologies during the catch-up phase. Their efforts were protected initially by the policy of the Ministry of International Trade and Industry (MITI) until they were ready to face global competition. In the 1950s, at the request of the Japan Business Federation, a comprehensive public organization of S&T management was established. In 1956, the Japan Science and Technology Authority was established in the Prime Minister's Office, facilitating research, reducing dependence on foreign technology, and strengthening linkages between the academia and industries. In 1959, the Council for Science and Technology was established to guide a national S&T policy.

**Catch-up phase (1960–1970s)**

From the mid-1960s, the focus shifted to the development of in-house indigenous technologies. At this time, research on building indigenous technologies was avoided in the private sector because of the long-term, high-cost, and high-risk investment involved. In 1966, the government implemented a "large-scale industrial R&D system" to induce technological innovation and spillover effects. The system raised the necessary budget and controlled the risks of large industrial research activities. The government selected strategic areas; subsidized technology development for private companies; and supported efforts in promising industries in private companies, universities, and national laboratories. Japan expanded access to all levels of education. Consequently, the number of researchers, including scientists and engineers, increased more than four times from 2.8 to 11.3 per 1,000 people.

**c. Post catch-up phase (1980s–present)**

The economic and technological gap between Japan and the US narrowed as industrial productivity increased sharply in the late 1980s. Japanese firms showed remarkable performance globally. Private investment in new equipment and machinery soared. Several Japanese companies (e.g., Sony Corporation, Panasonic Corporation, Toyota Motors, and Softbank) seized the global market with advanced technology that took the market share from major competitors in the US and Europe. As a result of the sharp increase in Japan's trade

surplus in the 1980s, business relationships with several business partners became even tenser (UN ESCAP, 2018). During the post catch-up phase, Japan had to develop its own technology trajectories instead of following a proven benchmark model. It focused on complex and sophisticated technologies, such as biotechnology and fine chemistry, while investing on basic research. Changes in the STI governance system by cabinet were relatively frequent; however, the mid- and long-term strategies represented by the master plan of S&T from 1st to 5th were consistent based on the Science and Technology Basic Law enacted in 1995.

**Table 6: Shift in Japan's Innovation Policies after Enacting the Science and Technology Basic Law** (1996–present)

| Classification | Shift in Innovation Policies |
|---|---|
| 1st S&T Basic Plan (STBP) (1996–2000) | • Expansion of existing research apparatus, promoting a new R&D system for the country<br>✓ Strengthening university–industry linkages<br>✓ Extension of international exchange programs<br>✓ Commercialization of intellectual assets<br>✓ Increased funding of competitive research grants (total of 17 trillion yen) |
| 2nd STBP (2001–2005) | • More expansion of existing R&D system<br>✓ Increased funding (total of 24 trillion yen) on competitive funding, strengthening basic research<br>✓ Societal goals were included in S&T policies<br>✓ Four priority domains were encouraged by the government: life sciences (including biotechnology), IT, environmental sciences, nanotechnology, and new materials |
| 3rd STBP (2006–2010) | • Promotion for achieving high-quality research results<br>✓ Support the autonomy of young researchers<br>✓ Reform graduate education<br>✓ Increase competitive funding (total of 25 trillion yen) |
| 4th STBP (2011–2015) | • Use of STI to address social and economic challenges<br>✓ Recovery and revitalization of Japan as a response to four major challenges, such as recovery from the 2011 Great East Japan Earthquake |
| 5th STBP (2016–2021) | • More comprehensive innovation strategy toward society 5.0[2], a shift from technology-driven innovation policy to society-centered and challenge-driven innovation policy<br>✓ Responding to challenges of digitalization and connectivity across all levels of Japanese society |

Source: Authors' creation based on Carraz and Harayama (2018).

More recently, Japan is leveraging innovation policies to address social "issues," such as aging, disasters, and environmental problems. Japan is trying to convert itself into a "leading country in solving the social challenges" to transform its various challenges into a growth engine by 2020. Looking at the formation of Japan's grand new STI governance, Abenomics (introduced in December 2012) is characterized by a strategy to overcome Japan's lost 20 years and aims to achieve high growth.

Japanese manufacturing has led to the technological competitiveness of Japanese products for the past two decades; however, leading companies have been experiencing recession recently. Since the launch of the second Abe regime, Japan aims for rebirth as an "S&T superpower" as one of the growth strategies. Therefore, it seeks to change the government system for the actual justification of S&T and the acquisition of overseas markets. Under the mid- and long-term policies, the comprehensive strategy for STI is selected every year. Such strategies focus on Japan's S&T policy, such as the National Energy and Environmental Innovation (2050) strategy, Innovative Research and Development Promotion Program, and Strategic Innovation Creation Program. The Comprehensive Council for Science, Technology, and Innovation is in charge of the function of S&T

[2] A society that can provide the necessary goods and services to the people who need them promptly and sufficiently; a society that can respond precisely to a wide variety of social needs; a society in which all people can readily obtain high-quality services, overcome differences of age, gender, religion, and language, and live vigorous and comfortable lives.

budgeting, linkages among academia, public institutions and industry, and R&D evaluation to support innovative research investments beyond the existing framework.

As a strategy for creating new business models in the era of the Fourth Industrial Revolution, Japan has been attempting new ways that combine bottom–up and top–down approaches. The national government sets the goals and time schedules to achieve by sector, each local government dictates deregulation, and companies identify new regulations or advancement from the roadmap and decide their policies on R&D or facility investment. Mid- and long-term milestones set performance targets (KPIs). These targets assume specific circumstances that aim to foster private investment by providing policy predictability of when and what regulations or institutions will be overhauled by the government.

**3. Innovation Policy Governance**

During the phase of industrialization and catch-up after the Second World War, the responsibilities of the national government of Japan are formulating and implementing nationwide comprehensive policies for promoting STI. Furthermore, the regionalization reform with the top–down decentralization strategy is important. Japanese local governments are responsible for formulating and implementing policies for promoting STI corresponding to national policies according to the local characteristics. For example, in line with the public research institute (PRI) decentralization, Tsukuba Science City was established during the 1970s, followed by Kansai Science City during the 1980s. Several policy instruments, such as industrial relocation promotion laws and factory location laws, were enacted to resolve regional disparities at those times. Moreover, Japan had a long-established and extensive support system for SMEs at the local and regional levels.

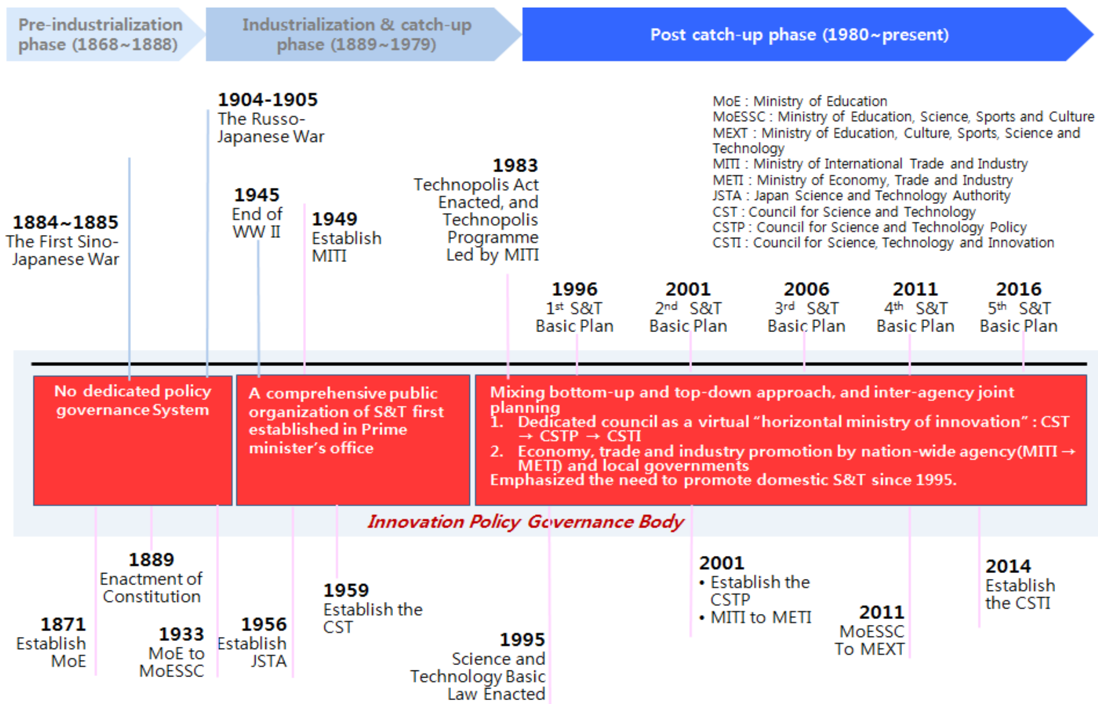
In 1980s, the MITI led Technopolis Program based on the Technopolis Act (1983) for promoting local economic development explicitly. By the end of the 1980s, 26 local sites officially participated in the program, spreading the resources widely and thinly. However, the mismatch between the industrial policy and STI policy remained unresolved at the local level. Local linkages within the Technopolis areas were weak, and industrial policy instruments, such as tax incentives and large-scale infrastructure investments, were more useful for large firms rather than startups or SMEs.

In 1990s, Japan experienced macro-economic stagnation. Relationally weak home demand for manufactured products burst its bubble economy, contributing to the ongoing restructuring and internationalization of the Japanese economy. Particularly, large firms moving production overseas and cutting domestic SMEs out of the supply chain. In terms of STI policy governance, highly comprehensive approaches were required. Especially, the abolition of the Council for Science and Technology in 2001 and the establishment of an alternative Comprehensive Council for Science and Technology were important changes.

The Comprehensive Council for Science and Technology is one of four important councils located in the Cabinet Office. The authority to coordinate and plan nationwide comprehensive STI policies was strengthened. In Japan, under the Framework Act on Science and Technology, the Comprehensive Council for Science and Technology established a framework for STI master plans and presented mid- to long-term strategies and visions for S&T policy. The first STI master plan was prepared by the previous Council for Science and Technology, whereas the 2nd through 4th STI master plans were prepared by a Comprehensive Council for Science and Technology. Rather than having strong top–down leadership, Japan is bringing together the policies planned by each ministry from the bottom up, taking a method that is determined through compromise under the direction of the Cabinet Office of Science and Technology Policy.

Japan's super smart society, a concept that first appeared in the 5th master plan for S&T since May 2016, aims to strengthen industrial competitiveness and solve social problems. Comprehensive STI meetings function as command towers and promote participation in industry, academia, and research. The master plan was prepared by the Comprehensive Council for Science, Technology, and Innovation under the Cabinet Office.

**Figure 1: Changes in Japanese Innovation Policy Governance Body Over Three Phases**




Source: Authors' creation.

## B. Republic of Korea

### 1./ Performance of Innovation Policies

The ROK is a well-known country that achieved a great successful catch-up through a timely usage of various policies toward innovation. Table 7 shows that over the last five decades, the ROK experienced dramatic growth in innovation input and output and economic growth. The ROK also became a country where companies led innovation, with private R&D expenditure surpassing public R&D spending since the mid-1980s.

**Table 7: Chronological Changes in the Performance of the Republic of Korea's Innovation Policy**

| Classification | | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Economic growth | GDP (billion US$) | 4 | 9 | 65 | 279 | 562 | 1,094 | 1,619 (12th) |
| | GDP per capita (US$) | 158 | 279 | 1,705 | 6,516 | 11,948 | 22,087 | 31,363 (29th) |
| | GNI per capita (US$) | 120 (in 1962) | 280 | 1,860 | 6,360 | 10,740 | 21,260 | 30,600 (26th) |
| Innovation input | R&D expenditure (% of GDP) | n/a | 0.38 | 0.54 | 1.62 | 2.18 | 3.47 | 4.23 (in 2016) |
| | R&D expenditure (public vs. private) | 97:3 (in 1963) | 71:29 | 49:41 | 15:85 | 28:72 | 28:72 | 22:78 (in 2017) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Researchers in R&D (per million people) | n/a | n/a | n/a | 2,173 (in 1996) | 2,287 | 5,330 | 7,113 (in 2016) |
| | Technicians in R&D (per million people) | n/a | n/a | n/a | 625.0 (in 1996) | 447 | 960 | 1,232 (in 2016) |
| Innovation output | High-technology exports (% of manufactured exports) | n/a | n/a | 15.9 | 18.0 | 35.1 | 29.5 | 26.5 (in 2016) |
| | Patent applications, residents | n/a | n/a | 1,241 | 9,082 | 72,831 | 131,805 | 159,084 (in 2017) |
| | Patent applications, nonresidents | n/a | n/a | 3,829 | 16,738 | 29,179 | 38,296 | 45,691 (in 2017) |
| | No. of scientific and technical publications | n/a | n/a | n/a | 11,324 (in 1999) | 23,201 (in 2003) | 50,935 | 63,063 (in 2016) |

Source: Authors' creation based on the DB provided by World Bank and KOSIS.

## 2. Evolution of Innovation Policy

The ROK's innovation policies have evolved in three phases. In the pre-industrialization stage, The ROK could not afford to think about innovation or S&T policies because of the urgent need to resolve the extreme shortage of commodities and reconstruction after the war. In the industrialization and catch-up phase, various policy instruments enhancing the ROK's S&T capabilities emerged because the ROK realized that S&T was an important approach for industrialization and economic development. In the post catch-up stage, S&T-oriented policies included the concept of innovation as a result of S&T and extended to STI policies. Innovation policies that address social problems and S&T issues are recently emerging.

### a. Pre-industrialization phase (1945–1959)

The ROK was out of the Japanese colonial period in 1945. However, the Korean War broke out in 1950, less than five years after gaining independence. Consequently, all infrastructures were destroyed, and the ROK was placed under the US military regime. During this phase, the US economic aids played a substantial role in the development of Korean economy. From 1946 to 1976, the US gave the ROK $6 billion worth of economic aid, which matched the total aid to all African countries (Kim, 2014). Different from other US beneficiary countries, the ROK used most of its aid building infrastructure and fighting illiteracy. Thus, the illiteracy rate in the ROK decreased from 78% in 1945 to 22% in 1959 (Kim, 2014). The ROK also implemented farmland reform, which raised the proportion of its farming population from 35% in 1945 to 88% in 1950 (Kim, 2014). Accordingly, farmers could afford to educate their children. The ROK used import substitution policy rather than export-oriented strategy to meet domestic demand through increasing production of everyday necessities (National Archives of Korea Website). Last, it focused on stabilizing prices by keeping grain prices, interest rates, and exchange rates low.

**b. Industrialization and catch-up phase (1960–1999)**

Although the ROK used various policy instruments, the consistent policy philosophy was government-led, export-oriented, industrialization-led, and high growth (OECD, 2014). On this basis, the major policies that Korea used during this period are as follows.

First is the Five-year Economic Development Plan (UN ESCAP, 2018; OECD, 2014; Encyclopedia of Korean Culture Website). The plan was initiated in 1962 and lasted seven times until 1996, before the ROK was placed under the IMF's bail-out program due to the Asian Financial Crisis in 1997. This policy set clear national objectives and orchestrated actions across industry, technology, trade, education, and infrastructure sectors to support the creation of domestic capabilities. A key actor of the plan was the Economic Planning Board (EPB) as a planning agency. The goal of the plan also changed over time. It was initially an imperative plan that emphasized finding and nurturing investment projects and later changed into an indicative plan that encouraged the involvement of private firms.

Second is leveraging *chaebols*, which are family-controlled conglomerates (UN ESCAP, 2018; OECD, 2014). *Chaebols*, such as Samsung, Hyundai, and LG, emerged and played a leading role in economic development. The Korean government provided foreign currency, preferential financing, and other privileges to *chaebols* in exchange of achieving economies of scale in matured industries, developing strategic industries, and export promotion.

Third is the shift from light to heavy and high-technology industry by cultivating R&D actors, increasing R&D investment and human resources, and establishing institutional settings (Choi, 2003; OECD, 2009). The ROK realized the importance of domestic R&D capability because technology protectionism of advanced economies made acquiring advanced technology more difficult than before, and the development of light industry was not helpful in catching up with advanced economies. Thus, the Government of the ROK conducted the activities (Table 8) that resulted in building an NIS by enhancing the capabilities of firms, government research institutions (GRIs), universities, and institutions, which are the main components or actors of NIS.

Fourth is importing advanced technologies through foreign debts rather than foreign direct investment (FDI) (UN ESCAP, 2018). The ROK limited FDI to ensure independence from multinational firms. The Government of the ROK adopted foreign loans as a key tool that encouraged indigenous firms to acquire, assimilate, and improve advanced technologies. Consequently, indigenous firms had time to build their technological capabilities without direct competition from multinational firms.

Last is running the large-scale and mid- and long-term national R&D programs (National Archives of Korean Website). To cultivate national S&T capabilities and enhance core industrial technologies, the ROK planned and ran the national R&D programs in areas that were challenging to be developed by private firms alone. In the national R&D programs, GRIs played a vital role as a coordinator, innovator, and cooperator, and private firms participated in programs with the private–public matching funds. The most successful national R&D projects include localization of TDX, DRAM, and high-speed railway; commercialization of CDMA and DMB; standardization of WiBro; and launch of Naro rocket.

**Table 8: Major Activities for Enhancing the Republic of Korea's S&T Capabilities (1960s–1990s)**

| Year | Major Activities |
|---|---|
| 1960s | • Establishing KIST in 1966<br>• Establishing the Ministry of Science and Technology (MoST) in 1967<br>• Enforcing the S&T Promotion Act in 1967 |
| 1970s | • Establishing KAIST in 1971<br>• Establishing many GRIs in the field of heavy and chemical industries from mid-1970<br>• Starting construction of Daeduk Science Park in 1974 |

| Year | Major Activities |
|---|---|
| 1980s | • Liberalizing technology licensing<br>• Launching the first national R&D program around MoST in 1982<br>• Promoting private firms' research institutes<br>• Reforming financial and tax incentives to stimulate private firms' R&D investment |
| 1990s | • Extending national R&D program to other many ministries<br>• Promoting university research centers<br>• Introducing new types of national R&D programs for core technology development<br>• Strengthening patent support system: enforcing the Invention Promotion Act in 1994<br>• Establishing inter-ministerial coordination body: Presidential Advisory Council on S&T (PACST) in 1991 and National S&T Commission (NSTC) in 1999 |

Source: Choi (2003)

**c. Post catch-up phase (2000–present)**

The ROK has been under pressure of changing its catch-up-oriented development policy to overcome the following challenges (STEPI, 2014): 1) continuous decline in productivity and economic growth since the Asian Financial Crisis in 1997; 2) The PRC overtaking the ROK's main industries, such as shipbuilding, steel, machinery, and electronics; 3) growing awareness of sustainable growth by solving the issues of environment, public health, and aging; 4) lower quality of public R&D compared with high increase of its quantity; 5) decline of entrepreneurship and innovation capacity of SMEs due to favorable policies for *chaebols*; and 6) necessity for preemptive strategy of new technology and market under the Fourth Industrial Revolution.

To address these challenges, the ROK produced various innovation policy instruments, coordinated by promulgation of national laws and plans (OECD, 2013). Particularly, the Framework Act on Science and Technology was enforced in 2001, and it is the legal basis for Five-year STBP[3]. The STBP is the ROK's overarching guide for the conduct of STI policy, and it is an important mechanism of improving policy coherence by collaboration and coordination across all ministries. In addition to the STBP, the Basic Research Promotion Plan was implemented according to the legal basis of The Researchers of the Basic Sciences Promotion Act established in 2008 (OECD, 2009). Table 9 shows two major changes of Korean innovation policy. First, innovation policy includes issues for improving human society, as well as economic and scientific development issues. Second, major policy instruments for solving six problems are 1) SME-centered R&D investment; 2) new industry and job creation through preparation for the Fourth Industrial Revolution; 3) manufacturing industry reform; 4) service industry innovation; and 5) R&D creating disruptive innovation.

**Table 9:Changes in Innovation Policies for the Last 20 Years**

| Classification | Vision 2025 of STBP | Vision 2040 of STBP |
|---|---|---|
| Government shift in innovation policies | Roh Moo-hyun<br>• Government-led policy → private and industry-led policy<br>• Development-oriented → diffusion-oriented<br>• Closed R&D system → globally networked R&D system<br>• Supply-dominated R&D investment strategy → demand-dominated R&D investment strategy<br>• Short-term technology development strategy → long-term technology development strategy<br>• No IPR system → enhancing IPR system | Moon Jae In<br>• Short-term performance and goal-oriented → long-term and disruptive innovation-oriented<br>• Lack of convergence and cooperation → increasing convergence and cooperation through an active innovation ecosystem<br>• Absence of next growth engine → accelerating new industry and job creation<br>• Lack of competence in service industry → nurturing service industry<br>• Economic growth-oriented → Improving quality of life and solving social problems, such as diseases, environment, climate |

[3] The STBP was established as a part of the Five-year Economic Development Plan for S&T since the 1960s (Encyclopedia of Korean Culture Website).

| Classification | Vision 2025 of STBP | Vision 2040 of STBP |
|---|---|---|
| | • No systematical NIS → an S&T-led NIS | change, unemployment, and lack of resources<br>• Financial/tax support-oriented for SMEs and start-ups → R&D investment-oriented for SMEs |

Source: Authors' creation based on information from Ministry of Science and Information and Communication Technology (ICT, MSIT; 2018) and MoST (2003).

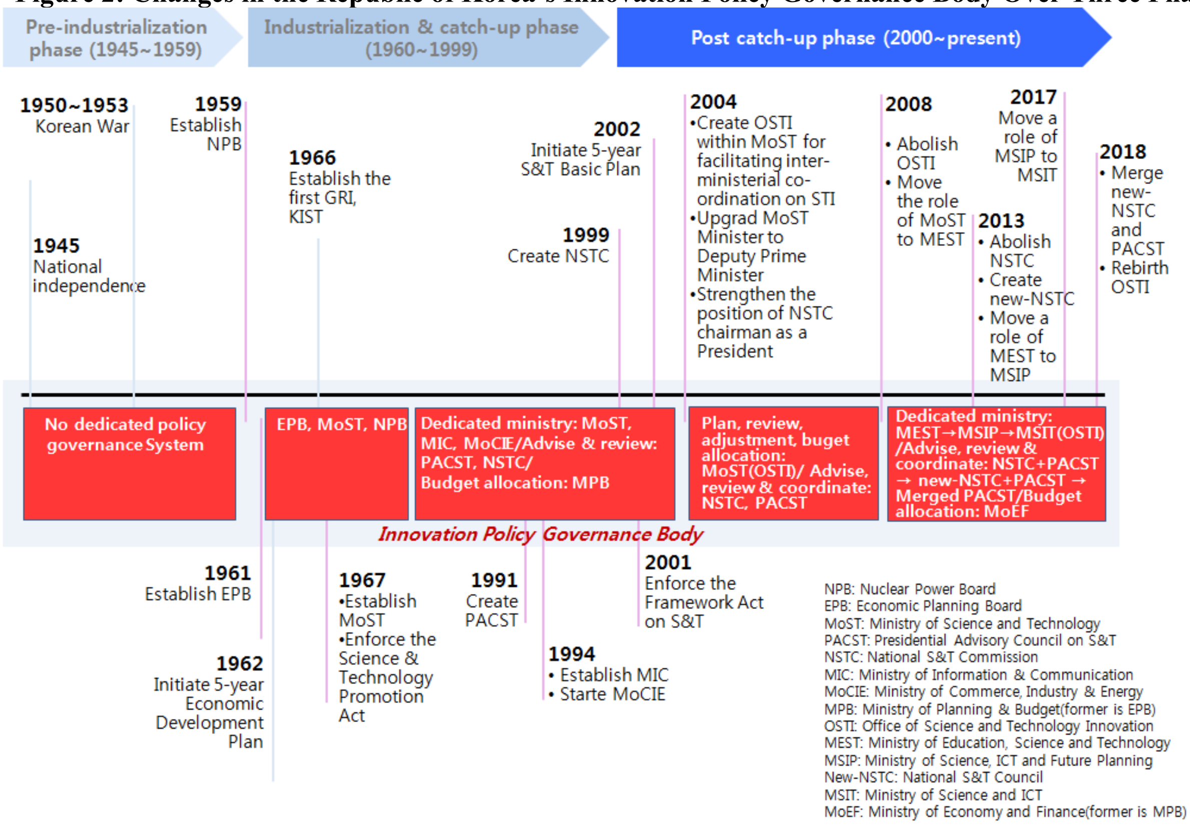
### 3. Innovation Policy Governance

Figure 2 shows that the ROK's innovation policy governance body has undergone several changes. Before industrialization, no organization was dedicated to policies. In the 1960s and 1970s, S&T were needed for technology evaluation and selection in industrialization and export expansion. Therefore, along with MoST established in 1967, EPB, and the Nuclear Power Board, which played major roles in the Five-year Economic Development Plan, became the key organizations of innovation policy governance. Throughout the 1980s, 1990s, and early 2000s, many ministries competitively participated in making S&T policies based on government-led economic growth policy philosophy. This phenomenon resulted in overlapping investments and waste of resources. Thus, the ability to coordinate policies across ministries was urgently needed. During this time, three ministries, namely, MoST, Ministry of Information and Communication, and Ministry of Commerce, Industry, and Energy, became dedicated ministries because they accounted for the largest amounts of national R&D budget. The Ministry of Planning and Budget was in charge of budget allocation.

In response to the need for strong coordination ability, the Roh Moo-hyun administration implemented three measures in 2004. First, the Office of Science and Technology Innovation was installed in MoST to facilitate policy coordination among ministries. OSTI acts as a channel between the NSTC and ministries. Second, the MoST minister was upgraded to deputy prime minister and given comprehensive authority, such as planning, deliberation, adjustment, and budgeting. Third, the NSTC chairman was upgraded to president to have the authority to adjust all ministries. During the Roh Moo-hyun administration, the ROK had the strongest innovation policy governance system centered on MoST. The Lee Myun-bak administration launched in 2008, abolished OSTI, and reduced the authority of MoST.

Since the Roh Moo-hyun administration, the dedicated ministry has changed from the MoST to the Ministry of Education, S&T and the Ministry of Science, ICT, and Future Planning, and recently became Ministry of Science and ICT. Regarding the advisory, reviews, and coordination body, NSTC played a key role during the Lee Myun-bak administration, and the new NSTC then took that role during the Park Geun-hye administration. The Moon Jae-in government recently merged new NSTC and the PACST into one advisory body. The government also rebirthed the OSTI of the Roh Moo-hyun administration to build a stronger innovation policy governance system. However, the authority of budgeting still rests in the Ministry of Economy and Finance.

**Figure 2: Changes in the Republic of Korea's Innovation Policy Governance Body Over Three Phases**




Source: Authors' creation.

## C. People's Republic of China

### 1. Performance of Innovation Policies

The PRC has successfully acquired the market economy in the socialist planned economy, achieved catch up in the short term, and is expected to overtake the US in terms of GDP by 2030, although GDP per capita is low. With the reform and opening in 1978 and the World Trade Organization (WTO) accession in 2001, the NIS has also shifted from government- to private sector-led. Sources of innovation investment have also changed from FDI to indigenous firms. According to the OECD, the share of the PRC's R&D spending accounted for only 0.72% and 0.893% of GDP in 1997 and 2000, respectively. Since then, its share rapidly increased to 2.129% and 2.18% in 2017 and 2018, respectively. At present, the PRC spends more on R&D than Japan, Germany, and the ROK combined and only lags behind the US in terms of gross expenditure. In 2016, the PRC's spending accounted for approximately 20% of global R&D expenditure. In terms of the source of R&D funding, the PRC has worked to boost the role of business enterprises in driving innovation forward. In 1997, the private sector contributed only 42.9% of R&D spending and surged to 60% in 2003, 72% in 2010, and 76.6% in 2016; whereas direct R&D funding from the government is declining. From 1997 to 2016, the percent of R&D financed by the government dropped from 55% to 20%, placing the PRC on a level comparable with the US (25.1%) and the ROK (22.7%), but considerably below that of Russia (68.2%) and Mexico (67.4%).

**Table 10: Chronological Changes in the Performance of PRC Innovation Policies**

| Classification | | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Economic growth | GDP (billion US$) | 59 | 92 | 191 | 360 | 1,211 | 6,087 | 13,608 (2nd) |
| | GDP per capita (US$) | 89 | 113 | 317 | 959 | 4550 | 1,094 | 9,770 (67th) |
| | GNI per capita (US$) | n/a | 120 | 220 | 330 | 940 | 4,340 | 9,470 (62th) |
| Innovation input | R&D expenditure (% of GDP) | n/a | n/a | n/a | 0.7 (in 1991) | 0.9 | 1.7 | 2.1 (in 2017) |
| | R&D expenditure (public vs. private) | n/a | n/a | n/a | 55:42.9 (in 1997) | 30:60 | 24:72 | 20:76 (in 2016) |
| | Researcher in R&D (per million people) | n/a | n/a | n/a | 438 (in 1996) | 542 | 890 | 1,206 (in 2016) |
| Innovation output | High-technology exports (% of manufactured exports) | n/a | n/a | n/a | 6.4 (in 1992) | 19.0 | 27.5 | 23.8 (in 2017) |
| | Patent applications, residents | n/a | n/a | 4,065 (in 1985) | 5,832 | 25,346 | 293,066 | 1,245,709 (in 2017) |
| | Patent applications, nonresidents | n/a | n/a | 4,493 (in 1985) | 4,305 | 26,560 | 98,111 | 135,885 (in 2017) |
| | No. of scientific and technical publications | n/a | n/a | n/a | n/a | 86,621 (in 2003) | 316,915 | 426,165 (in 2016) |

Source: Authors' creation based on the database provided by World Bank, MOST (2007), and OECD.

**2. Evolution of Innovation Policies**

The PRC's innovation policies have evolved through three phases. First is the pre-industrialization stage from the founding of 1949 before the reform and opening in 1978. At this stage, the PRC experienced socialist experiments, such as the Great Leap Forward movement (1958–1960) and the Cultural Revolution (1966–1976) under the socialist planned economy. Second, in accordance with the reform and opening up in 1978, the government set policy goals of increasing productivity based on the development of S&T and promoted the transition to the PRC socialist market economy. The PRC implemented a catch-up strategy based on its vast domestic market to attract FDI and cover scarce capital and technology. Third, as a post catch-up stage, the PRC emphasized its policy of supporting indigenous companies' exports and innovation based on their successful transition to a market economy.

**a. Pre-industrialization phase (1949–1977)**

After the foundation in 1949, the PRC established the Chinese Academy of Sciences to support the heavy and chemical industry priority policy and respond to the demands of S&T development; it launched the First Five-year Plan (1953–1957). In 1956, the Science Planning Committee, a department dedicated to S&T, was established under the State Council to create an innovation system centered on S&T. The 12-year transitional development plan (1956–1967) and the 10-year S&T plan (1963–1972) were enacted. Recognizing that S&T is a key element of modernization of agriculture, industry, and defense, the PRC mobilized the nation's capabilities to solve the core S&T problems of socialist construction. Locomotives and airplanes were produced in the PRC, and defense science, such as atomic bombs and missiles, progressed.

Agricultural population exceeded 80% of the population, and the gap in the economic environment between regions was wide. However, the PRC centralized distribution system of goods, mainly based on the Soviet-style planned economic system, was inefficient. Moreover, during the 10 years of the Cultural Revolution (1966–1976), many scientists were deported to rural areas for ideological issues. The accumulated research base (e.g., experimental facilities) was undermined, and the aggressiveness of scientists and engineers was suppressed. In addition, the innovation of this period was driven entirely by the state under the socialist planned economy. In the nondefense sector, no commercialization or demand existed for technology, and the technology gap with foreign countries widened.

**b. Industrialization and catch-up phase (1978–2010)**

The industrialization of the PRC proceeded in line with the gradual transition of the socialist planned economy system that differentiated the PRC's experience from other countries.

The first transition is from the socialist planned economic system to the market economy (1978–1980). The PRC's planned economy experienced a rapid change in 1978 at the third conference of the 11th Chinese Communist Party. On the methodological side, the PRC adopted a gradual approach, unlike the Soviet Union, which adopted a radical reform. To improve the inefficient people's commune system, the PRC introduced a system in 1978 where farming households were in charge of production. As a result, agricultural productivity increased substantially. The PRC government expanded its autonomous trade authority to local governments and businesses and designated and operated four special economic zones (i.e., Shenzhen, Zhuhai, Shantou, and Xiamen) to boost exports and attract foreign capital.

The second transition is from rural to urban reform and from agricultural to enterprise reform (1980–2000). The PRC government increased corporate productivity by providing incentives while ensuring managerial autonomy. Given the reform of state-owned enterprises (SOEs), modern corporate governance was formed. The corporate production responsibility system, which was implemented in 1987, was an opportunity for firms to decide on production and investment and secure the right of profit distribution beyond the state's management. With the introduction of the principle of the market economy from rural areas in the PRC, the perception that "S&T increases productivity" spread initially in the specialized economic zones. As a foreign trade revitalization measure, 14 port cities, including Dalian, Tianjin, Shanghai, and Guangzhou, were opened (1984.5), and Hainan Special Economic Zone (1988) and Pudong New District in Shanghai (1990) were established. The functions of the NSTC and the Chinese Academy of Sciences, which were suspended during the Cultural Revolution, were restored. On this basis, as the reform and opening began in earnest, the mechanism of absorbing and applying new technologies through the market opening and FDI began to work. Basic science was led by the state through the 863 Program (1986), and seven high-technology fields (i.e., biotechnology, aviation, information and communication, laser, automation, energy, and new materials) encouraged private companies to participate in reducing the technological gap with advanced countries. the PRC further expanded the market and economic transformation to the financial and foreign exchange sector. The PRC established modern banking systems, such as central, commercial, and banks, as well as nonbank financial institutions such, as insurance and trust companies (the State Council, December 1993). The People's Bank of China (1948), which was the only bank

(mono bank) under the Ministry of Finance (MOF) and a commercial and policy financial institution, only served as a central bank since 1995 when the People's Bank of China Act was enacted. Innovation funds were created in the PRC in 1998, which allowed small- and medium-sized technology-based companies to support insufficient R&D.

The third transition is from domestic-oriented economy to participation to the global value chain (2001–2010). The PRC entry into the WTO in 2001 served as a window of opportunity to take overseas capital and technology through FDI and increase its global market share. Along with the creation of an external favorable environment, the PRC government strengthened the technological capabilities of indigenous firms. Foreign-invested companies accounted for 25%–30% of the total R&D investment (OECD, 2008), and 1,050 public research institutes were privatized between 1998 and 2003. The PRC's domestic firms accumulated technological capabilities under the structure of cooperation between private and foreign-invested companies and public research institutes and universities by attracting advanced technology companies through the market opening policy.

In February 2006, the PRC government announced its mid- to long-term S&T development plan (2006–2020) and presented strategies for fostering independent innovative capabilities and building innovative countries. The exchanging market to technology strategy transformed into an independent innovation strategy to improve the innovation capability of local businesses. The PRC announced shifting PRI-oriented innovation systems to business-oriented ones and reducing technology's external dependence by up to 30% by 2020 (KIEP, 2006). The PRC government also announced a plan to attract 2,000 international students from overseas to cultivate at least 1,000 talented people to contribute to the national S &T development.

Table 11 shows the major S&T policies implemented in the industrialization phase in the PRC.

**Table 11: Major Activities for Enhancing the People's Republic of China's S&T Capabilities**
(1970s–2000s)

| Year | Major Activities |
|---|---|
| 1970s | • Economic reform and opening policy were launched (1978).<br>• From 1975 to 1978, Deng Xiaoping launched a "rectification" of the economic, S&T, and education systems damaged by the Cultural Revolution. After the death of Mao and the arrest of the Gang of Four, Deng's ideas were reflected in the Science Conference of 1978. |
| 1980s | • Special economic zones in four provinces (i.e., Shenzhen, Zhuhai, Guangdong, and Xiamen) were established in 1980.<br>• The Central Committee of the Chinese Communist Party (CCPCC) issued the decisions on the reform of the economic, S&T, and education systems in 1984, 1985, and 1985, respectively.<br>• The Beijing Experimental Zone for New Technology and Industrial Development (Zhongguancun) was established in 1988.<br>• Fourteen port cities (e.g., Dalian, Tianjin, Shanghai, and Guangzhou) were opened (1984.5).<br>• Hainan Special Economic Zone (1988) and Pudong New District in Shanghai (1990) were newly established. |
| 1990s | • Following Deng's proposal of faster reform, the Fourteenth Congress of the CCPCC proposed the establishment of a socialist market economy.<br>• The Technology Spreading Program was introduced in 1990.<br>• Deng Xiaoping re-emphasized the reform-opening policy by visiting major southern regions for 35 days in 1992.<br>• Innovation Fund for Technology-based SMEs was established in 1999. |
| 2000s | • The People's Republic of China joined WTO in 2001.<br>• The 10th Five-year (2001–2005) Economic Development Plan proposed the core goal of building a society where more than one billion people can enjoy the living standards of the middle class by 2020 (Xiao Kang Society, 2002) |

| Year | Major Activities |
|---|---|
| | • Firms' innovation capabilities were enhanced, and public research was commercialized.<br>• In 2008, the PRC government announced a plan to attract 2,000 international students from overseas to cultivate at least 1,000 talented people.<br>• Mid- to long-term S&T development plan was established (2006–2020) |

Source: Liu et al. (2011); OECD (2008).

#### c. Post catch-up phase (2010–present)

The PRC economy has been growing at least for the last 40 years. The PRC's share of global commodity exports rose from 0.9% in 1980 to 9.7% in 2010 and 11.5% in 2017; and its share of global GDP rose from 1.8% in 1978 to 15.2% in 2017. On the basis of this achievement, the Xi Jinping administration announced the so-called "China Dream," which means establishing a horizontal relationship with the US, finding a place for the PRC in the international community through Chinese-style superpower diplomacy, and playing a role as a hegemony country for the development of the world economy. The strategic transitions are as follows.

The first transition is from public and government-driven to private-driven. The 12th Five-year Plan of the Hu Jintao government (2011–2015) emphasized new rural construction and industrial upgrading, whereas the 13th Five-year Plan (2016–2020) of the Xi Jinping government emphasizes innovation in all areas. Strategically, the PRC has emphasized the "exchange market to technology" strategy since the early 2000s but began to emphasize the "indigenous innovation" policy. In line with this direction, the PRC has emphasized private creativity and entrepreneurship rather than the government-driven development.

The second transition is the industrial upgrading by digital convergence. The digital paradigm that emerged with the Fourth Industrial Revolution has served as a driving force behind the PRC's post catch-up strategy. Accordingly, the PRC declared a breakthrough policy in the New Normal situation of the low-growth economy through digital innovation. The PRC aims to raise AI technology and application to levels comparable with advanced countries by 2020 and become an innovative power alongside the US by 2045 through China Manufacturing 2025, Internet Plus, and Next-Generation AI Development Plan (2017). The PRC Manufacturing 2025 is a three-stage development strategy aimed at securing the PRC's competitive advantage over the next 30 years. It aims to solidify its position as a manufacturing giant by 2020, enter a manufacturing powerhouse at the level of Germany and Japan in 2025, and secure the world's strongest competitiveness in major industries as the world's first manufacturing group after 2035. The PRC Manufacturing 2025 supports 10 core industries and 23 sectors, including new energy vehicles, 5G, high-speed rail, industrial robots, semiconductors, new materials, biomedical devices, marine plants, and aerospace. The goal is to increase the independence of the entire manufacturing value chain by increasing parts and material localization rates by 40% and 70% by 2020 and 2025, respectively.

The Internet Plus strategy aims to promote the convergence of ICT and traditional industries by 2025 and the innovation and upgrade of industrial structure to create a digital-based ecosystem. Internet Plus selects 11 major tasks (e.g., manufacturing, agriculture, energy, finance, public welfare, logistics, e-commerce, transportation, eco-environment, and AI) and upgrades the industrial structure.

The Next-Generation AI Development Plan aims for the PRC to be the world's leading nation in AI technology and application in 2020; artificial intelligence theory in 2025; and artificial intelligence theory, technology, and application in 2030. To realize this strategy, the PRC government is attempting to create an open, cooperative AI technology innovation system and make all industries and the society smarter with AI-based technology. The PRC government invests heavily in next-generation supercomputers, whereas private sectors, such as Baidu and Tencent, have established AI l aboratories in the US.

The third transition is from urban to rural and from east to west. While the eastern coastal areas of the PRC, such as Beijing, Shanghai, and Shenzhen, have achieved rapid economic growth through intensive

investment after reform and opening up, the western inland fell into underdevelopment. The Western development was initially confirmed as the core project in the 10th Five-year Plan and took shape through the 13th Five-year Plan (2016–2020). Phase I (2000–2010) establishes a foundation for infrastructure investment; whereas Phase II (2011–2030) accelerates development, expands investment scale, and actively fosters specialized industries in the West. Phase III (2031–2050) will close the regional development gap. The PRC is currently in the second stage of western unit development. Different from the previous investment, the PRC is pursuing policies that can provide endogenous growth engines, such as fostering specialized industries, protecting the ecological environment, and improving public welfare.

As of 2017, the PRC ranked second in the world for R&D investment, 2nd for the registration of intellectual property rights (48,462, 13.4%), and 1st for the number of scientific and technical papers (426,000, as of 2016). The number of patents regarding AI surpassed that of the US and ranked 1st worldwide.

**3. Innovation Policy Governance**

Innovation policy systems of the PRC at the time of its foundation in 1949 were under the centralized Soviet-style governance. Moreover, the Great Leap Forward movement (1958–1960) and Cultural Revolution (1966–1976) adversely affected the S&T sector. The goal of early achievement of research shortened the long-term S&T plan and created many unrealistic research institutes. As basic research decreased and applied research was emphasized, even institutes and universities operated their own factories. The Chinese Academy of Sciences, which owned 106 research institutes in 1965, was reduced to 13 direct research institutes and 43 affiliated institutes in 1973, and the National Science and Technology Committee was canceled in 1970. Many scientists were criticized as reactionary intellectuals and deported to rural areas. Following the reform and opening in 1978, the PRC recognized economic development as the country's key goal and S&T as a practical means of realizing it. Research institutions destroyed during the Cultural Revolution began to be reorganized. In 1977, the NSTC restored its functions, and various suspended academic societies were reestablished. The function of the Chinese Academy was restored, the departments and local branches were activated, and basic science research began to be emphasized again. With the development of market systems and the reform of SOEs underway, the PRC drastically reduced its government bodies. In March 1998, the Chinese State Council's affiliated agencies were reduced from 40 to 29.

The key ministries in charge of the PRC's innovation policy are the State Council, MoST, and Ministry of Industry and Information Technology.

The State Council conducts administration under the basic policy of the Central Political Bureau Standing Committee (the highest organization of the Communist Party of China) and establishes the basic direction of national S&T policy. The State Council has established and operates the National Science and Technology Leader's Small Group (2018), which is a reform of the previous "National Science Technology and Education Leader's Small Group." As part of the reform of the party–government organization, this group discusses and reviews the national S&T development strategy, plans, and important policies. It also coordinates cooperation on critical S&T issues between ministries of the State Council and between central and provincial governments. The leading small group is headed by the prime minister of the State Council. The State Council has 15 direct organizations under its wing (e.g., China Academy of Sciences, the Chinese Academy of Social Sciences, the China Fair Trade Commission, the State Council Development Research Center, and the National Natural Science Fund), which affect the establishment of S&T policies. In addition, the Chinese Academy of Sciences is an independent research institute belonging to the State Council, which has a medium-to-long-term and independent R&D authority.

Under the State Council, MoST played an important role in creating and implementing a wide range of S&T policies. MoST covers all areas of the technology development chain, including basic research, high-technology development, technological commercialization, regional development, and improvement of quality of life through technology. MoST has the Science and Technology Information Institute, the Science and

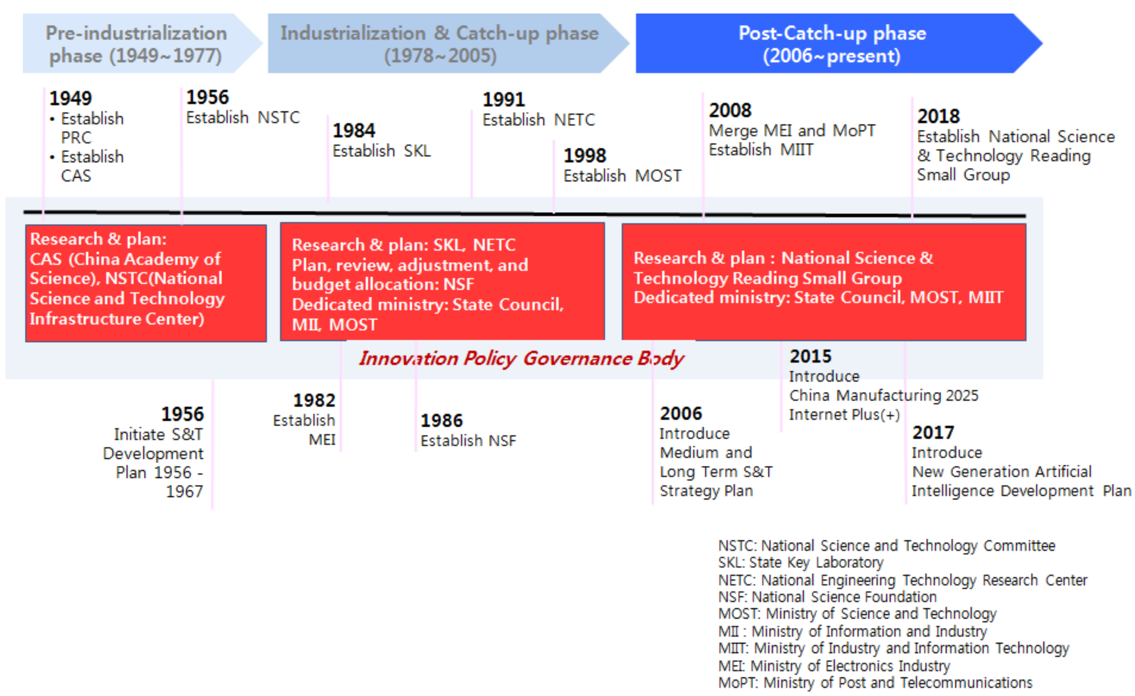
Technology Development Strategy Institute, and the National Center for Technology Innovation under its wing to help form policies.

In line with the world's trend of recognizing information and communication as an infrastructure of convergence industries rather than an IT industry alone, the MII was dismantled, and the MIIT was established in 2008 to foster the convergence between ICT and traditional industries. Policies on new technologies, such as AI and block chain, are mostly developed by MIIT. Other related ministries and research institutes under each ministry conduct research activities related to the ministry's work.

Another important part of the PRC's innovation policy is its connection to the regional innovation system. The region's special economic zones began in April 1979 when the central operation meeting decided to foster some areas of four cities (i.e., Shenzhen, Zhuhai, Shantou, and Xiamen) as special export zones centered on export manufacturing led by foreign-invested companies. In May 1980, Shenzhen, Zhuhai, Shantou, and Xiamen were ratified as special economic zones. With the launch of the Hainan Special Economic Zone in 1988, the five special economic zones of reform and opening were formally formed. These areas are the PRC's first-generation "special economic zones," which quickly emerged as a global processing-and-export base for producing and selling price-competitive labor-intensive products to overseas export markets by attracting foreign capital with unconventional benefits and combining them with the PRC's cheap labor. By the end of November 2013, 6 special economic zones, 6 new state-grade zones, 6 economic zones, 15 national comprehensive reform test zones, and 192 state-grade economic technology development zones were in operation.

In summary, the State Council is the top decision-making body in the PRC's S&T innovation governance, under which the National Science and Technology Education Leader's Small Group functions as a coordination channel. The ministers of relevant ministries participate in policy design. MoST and MIIT are the chief departments of S&T and industrial innovation policy. Local governments establish action plans based on the S&T policies of the central government.

**Figure 3: Changes in the People's Republic of China's Innovation Policy Governance Body Over Three Phases**




Source: Authors' creation.

**D. India**

**1. Performance of Innovation Policies**

Table 12 shows that India has rapidly grown to be the 7th largest economy in the world; however, its recent GDP and GNI per capita remain insufficient to reach that of the upper-middle-income country[4]. India has also presented a considerable improvement in innovation output since the 1990s. However, innovation inputs have not changed considerably over the past three decades. In addition, the number of patent applications by residents is only one-third of that by nonresidents. Indian innovation has considerably relied on foreign firms or foreigners. Another substantial unsolved issue remains: public institutions have still led India's R&D activities, that is, public R&D expenditure is higher than that of private R&D.

**Table 12: Chronological Changes in the Performance of India's Innovation Policy**

| Classification | | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Economic growth | GDP (billion US$) | 37 | 62 | 186 | 321 | 468 | 1,676 | 2,726 (7th) |
| | GDP per capita (US$) | 82 | 112 | 267 | 368 | 443 | 1,358 | 2,016 (143th) |
| | GNI per capita (US$) | 90 (in 1962) | 120 | 270 | 380 | 440 | 1,220 | 2,020 (136th) |
| Innovation input | R&D expenditure (% of GDP) | n/a | n/a | n/a | 0.65 (in 1996) | 0.77 | 0.82 | 0.62 (in 2015) |
| | R&D expenditure (public vs. private) | n/a | n/a | n/a | 76:24 | 77:23 | 62:38 | 56:44 (in 2015) |
| | Researchers in R&D (per million people) | n/a | n/a | n/a | 115.7 (in 1998) | 110.1 | 156.6 | 216.2 (in 2015) |
| | Technicians in R&D (per million people) | n/a | n/a | n/a | 111.2 (in 1996) | 85.5 | 101.1 | 95.6 (in 2015) |
| Innovation output | High-technology exports (% of manufactured) | n/a | n/a | 4.1 (in 1988) | 3.9 | 6.3 | 7.2 | 7.0 (in 2017) |
| | Patent applications, residents | n/a | n/a | 1,207 | 1,147 | 2,206 | 8,853 | 14,961 (in 2017) |
| | Patent applications, nonresidents | n/a | n/a | 1,817 | 2,673 | 6,332 | 30,909 | 31,621 (in 2017) |
| | Scientific and technical journal articles | n/a | n/a | n/a | n/a | 26,797 (in 2003) | 62,790 | 110,319 (in 2016) |

[4] See footnote 1.

Source: Authors' creation based on the DB provided by World Bank and MoST in India (2017).

## 2. Evolution of Innovation Policies

India's innovation policy has evolved in two phases, namely, pre-industrialization phase and industrialization and catch-up phase. In the pre-industrialization stage (1947–1955), India established many public laboratories and research institutions and built the political foundation for reflecting S&T on the national development plan. However, India failed in linking S&T and development plan. During the industrialization and catch-up period (1956–present), India issued a new S&T policy statement four times. All Indian S&T policies have paralleled the Five-year Plan. Starting with the Science Policy Resolution (SPR) in 1958, India published the Technology Policy Statement (TPS) in 1983, Science and Technology Policy (STP) in 2003, and Science Technology and Innovation Policy (STIP) in 2013. Four policy statements sequentially influenced India's innovation policy, evolving to a science-oriented, technology-oriented, science-industry synergy-oriented, and innovation-driven policy era.

### a. Pre-industrialization phase (1947–1955)

After India's independence from the British rule in August 1947, it pursued a mixed economic system based on "Soviet economic planning" and "Western industrial capitalism" while adopting parliamentary democracy as its political system (Krishna, 2001). India attempted to link S&T with national development plan early due to the influence from Jawaharlal Nehru's[5] strong convictions that S&T enables Indians to enjoy material and mental affluence. However, such an attempt was not made until closing the first Five-year Economic and Social Development Plan (1951–1956), even when India have established many national laboratories, research institutions, and the base for political commitment to science (Subramanian, 1987). Therefore, India was more interested in farming industries than industrialization. Moreover, it did not successfully link S&T with the national development plan.

### b. Industrialization and catch-up phase (1956–present)

In 1958, the Indian attempt of linking S&T with the national development plan was finally realized through the announcement of the SPR. Therefore, the overall direction and resource allocation for the S&T policies came from the Five-year Economic and Social Development Plan (hereinafter called the Five-year Plan) since the SPR. India's S&T policies have been expressed and promoted through resolutions and policy statements, without specific laws dedicated to S&T. Thus far, India has pronounced four major S&T policy statements including the SPR. They are the TPS in 1983, the STP in 2003, and the STIP in 2013. Therefore, the evolutionary direction of India's innovation policy is examined in this work by looking through changes of 12 Five-year Plans and four S&T policy statements (Table 13).

**Science-oriented policy era**: The main objective of the SPR is to foster, promote, and sustain the cultivation of science and scientific research in all its aspects (i.e., pure, applied, and education) to secure all benefits that can accrue from acquisition and application of scientific knowledge for the people of the country (Dhar and Shaha, 2014). During the first two decades, after the announcement of SPR, India witnessed the extension of research facilities to universities and other research centers, enhancement of existing national research facilities, and establishment of new technical universities [e.g., Indian Institute of Technology (IITs)] for higher education and engineering research (Sandhya, 2018). The second Five-year Plan (1956–1961) also commenced implementing heavy industries' first policy for industrialization. In the 1960s and 1970s since the SPR, India extremely adhered to science-oriented policies and performed R&D activities around the national basic research institutes. The result was a great success in the noncompetitive markets of defense, space, and nuclear, but less successful in competitive markets, such as electronics and automobiles (Sandhya, 2018). Furthermore, poverty remained a national burden (Dhar and Shaha, 2014).

[5] Jawaharlal Nehru was the first Prime Minister in independent India, from 1947 to 1964.

**Technology-oriented policy era**: India recognized the importance of technology, which has considerably higher possibilities of commercialization in the market compared with science. In 1983, India announced the TPS, which aimed to develop indigenous technologies, quickly absorb and improve imported technologies, achieve technological self-reliance and enhance technological competence (Yim, 1997). For achieving the TPS' main goal, that is, technological self-reliance, India attempted to provide fiscal incentives and direct R&D funds for companies who developed indigenous technologies and strongly regulated FDI and technology import. Such a regulation brought indigenous firms a limitation of successful development because they need to import advanced technologies or a technology transfer from global firms to develop their own technologies. India loosened this regulation in only the S/W industry through its establishment of the computer S/W export, development, and training policy. This policy was the key to India's huge success in the S/W industry.

**Science industry synergy-oriented policy era**: In 1991, India had to open its domestic market abroad because it faced a foreign exchange rate crisis. India needed a new S&T policy because it shifted its economic paradigm from closed to liberal; thus, it announced STP in 2003. India's S&T policy was influenced by its liberalization and added the following new instruments: 1) reduced regulations on FDI, foreign technology transfer, and import of technologies or capital goods; 2) emphasis on global cooperation in S&T; 3) encouraging export of high-technology products or indigenous technologies; 4) promotion of industry–university–public partnership; and 5) establishing the Trade-Related Intellectual Properties (TRIPs) compatible product patent system through the revision of Patent Act in 2005.

**Innovation-driven policy era**: India experienced a rapid economic growth, but it came up with a new policy because it recognized the lack of innovation and R&D investment, which is a key driver of industrial growth. The new policy called the STIP was announced in 2013 (KIAT, 2017). Given that this policy added a concept of innovation as a new focus, India's recent policies emphasized innovation-led S&T development and strong support for SMEs and start-ups. For fostering the manufacturing industry that has been considerably weaker than the service industry, various government-supported programs, such as *Make in India*, *Skill India*, and *Start-up India*, were established. For presenting technology roadmap by sector, *Technology Vision 2035* was prepared (KIAT, 2017). Lastly, from the SPR to the recent STIP, India has continually invested in nurturing R&D human capital; S&T education and training; and building, improving, and advancing public R&D facilities. India's investments have not effectively stimulated private sectors to invest in R&D, and its private R&D capability is comparatively lower than that of peer countries because its innovation is still led by the public R&D. Hence, India has yet to be successful in catching up even if it is the 7th largest economy in the world.

**Table 13: Evolution of India's Innovation Policy: Changes of Five-Year Plan and S&T Policy Statements**

<table>
<tr><th>Five-Year Plan</th><th>Ruler</th><th>S&T Policy and Instruments</th><th>S&T Policy Statements</th></tr>
<tr><td>1st Five-year Plan (1951–1956)</td><td rowspan="3">Jawaharla Nehru (1947–1964)</td><td>• Build national laboratories and research institutions</td><td></td></tr>
<tr><td>2nd Five-year Plan (1956–1961)</td><td>• Establish new technical universities (e.g., IITs) for higher education and engineering research<br>• Expand and enhance the existing national research facilities</td><td rowspan="3">Announced the SPR in 1958: Foster, promote, and sustain the cultivation of science and scientific research in all its aspects (i.e., pure, applied, and education)</td></tr>
<tr><td rowspan="2">3rd Five-year Plan (1961–1966)</td><td rowspan="2">• Promote basic and applied research<br>• Emphasize agriculture, nuclear energy, and engineering research<br>• Streamline commercial application of research outputs</td></tr>
<tr><td>Lal Bahadur Shastri</td></tr>
</table>

| Five-Year Plan | Ruler | S&T Policy and Instruments | S&T Policy Statements |
|---|---|---|---|
| | (1964–1966) | | |
| 4th Five-year Plan (1969–1974) | Indira Gandhi (1966–1977) | • Reiterate and promote commitments laid out in the 3rd Five-year Plan<br>• Enforce the Patent Act in 1972 (no patent in India's pharmaceutical industry → build India's specialty in production of generic drugs) | |
| 5th Five-year Plan (1974–1979) | Morarji Desai (1977–1979) | • Take a sectoral approach by appreciating sectoral needs<br>• Initiate the inter-institutional and integrated-approach projects | |
| 6th Five-year Plan (1980–1985) | Indira Gandhi (1980–1984) | • Promote technological self-reliance<br>• Encourage enterprises to implement reverse engineering and import substitution<br>• Strongly restrict technology import and FDI but mitigate the restrictions over the S/W industry through establishment of the CSE & SDT[6] policy and the Department of S/W Development in 1986<br>• Set up three S/W Technology Parks in 1990<br>• Provide fiscal incentives (e.g., tax reliefs on R&D expenditure and custom duty exemption) to promote indigenous technology development for firms<br>• Provide direct public funding of R&D for firms | Announced the TPS in 1983: Seek technological self-reliance |
| 7th Five-year Plan (1985–1990) | Rajiv Gandhi (1984–1989) | | |
| 8th Five-year Plan (1992–1997) | Narasimha Rao (1991–1996) | • Promote industrial (private) R&D<br>• Assist firms' indigenous technology development and commercialization through the adoption of "TDB Act[7]" in 1995<br>• Mitigate regulations on the technology transfer<br>• Alleviate restrictions on technology import and FDA<br>• Promote PPP programs (e.g., DPRP[8] in 1994) | India's '*liberalization*' in 1991 because of foreign exchange crisis |
| 9th Five-year Plan (1997–2002) | Atal Bihari Vajpayee (1998–2004) | | |
| 10th Five-year Plan | | • Enhance applied research-based R&D<br>• Strengthen gifted and talented education in S&T and bring up S&T human capitals | Announced the STP in 2003: Emphasize on the need to ensure synergy between |

[6] CSE & SDT policy stands for Computer Software Export and Software Development and Training policy, which was established in 1986.

[7] TDB Act stands for Technology Development Board Act, which assists firms that develop and commercialize indigenous technology or adopt imported technology for wider domestic applications. On the basis of this Act, the Technology Development Board was established in 1996.

[8] DPRP stands for the Drugs and Pharmaceutical Research Program, which was industry–institute joint research projects and was jointly funded by the government and the industry.

| **Five-Year Plan** | **Ruler** | **S&T Policy and Instruments** | **S&T Policy Statements** |
|---|---|---|---|
| (2002–2007) | Manmohan Singh (2004–2014) | • Link S&T research and all national development activities<br>• Promote the usage of S&T for job creation and improvement of livelihood<br>• Secure environmental conservation and ecosystem safety<br>• Encourage export of high-technology products or indigenous technologies<br>• Enhance PPPs<br>• Emphasize S&T global cooperation<br>• Revise the *Patent Act* in 2005: Switch to TRIPs' compatible product patent regime | scientific research and industry and integrate socioeconomic sectors with national R&D system for solving national problems (inherit the spirit of SPR of 1958) |
| 11th Five-year Plan (2007–2012) | | • Emphasize being a global innovation leader and reiterate most of 10th Five-year Plan's policies<br>• Strengthen basic research (e.g., bioengineering, physics, chemistry, engineering, and cyber security)<br>• Implement mega science projects<br>• Foster cross-disciplinary technology areas<br>• Support SMEs in R&D, technology transfer, acquisition of patented technology, and technology management<br>• Start-up development and incubation<br>• Facilitate rural technology delivery | |
| 12th Five-year Plan (2012–2017) | Narendra Modi (2014–present) | • Establish world-class national S&T facilities<br>• Initiate technical partnership programs between federal and local governments<br>• Attract private sector investments in R&D while enhancing PPPs<br>• Increase the number of science teachers<br>• Mega-level investment to expand domestic and overseas R&D facilities thorough partnership<br>• Present technology road map by sector through the *Technology Vision 2035*<br>• Foster manufacturing industries: *Make in India* (attracting investment from global manufacturing firms), *Skill India* (education and training of job competency), and *Start-up India* (financial and nonfinancial support for start-ups) | Announced STIP in 2013: Seek a strong and viable Science, Research, and Innovation System for High-Technology-led path for India (SRISHTI) |

Source: Authors' creation based on Sandhya (2018); Dhar and Saha (2014); KIAT (2017); Yim (1997).

### 4.3 Innovation policy governance

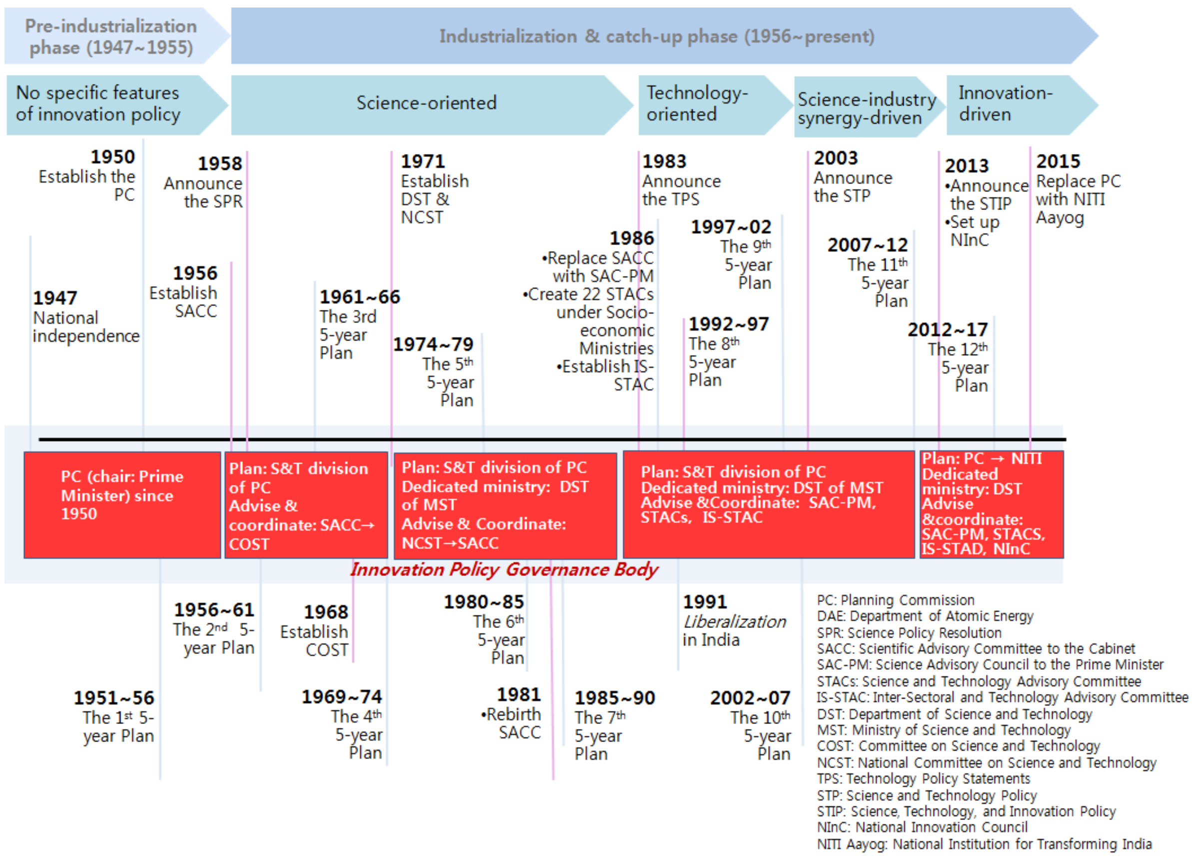
Figure 4 shows that India's innovation policy governance system has undergone several changes following the announcement of four S&T policy statements. Before the SPR in 1958, the Planning Commission (PC), whose chair is the Prime Minister, was established in 1950 for creating the first Five-year Plan (1951–1956). The PC created programs of building public R&D facilities and other infrastructures as part of national development plans, although it did not have any independent S&T policy direction. Since the SPR, the PC established the S&T division within itself for dedicating to the establishment of S&T policies. In addition, the Scientific Advisory Committee to the Cabinet (SACC) was created as an advisory and coordinator body for S&T policies. The SACC was later replaced by the Committee on Science and Technology (COST). These organizations, PC and SACC (later, COST), led S&T policies for a decade.

In 1971, the Department of Science and Technology (DST) was created under the MoST, and the COST was replaced by the NCST. Thereafter, NCST was abolished, and the SACC was reborn as an advisory and coordinator body in 1981. The DST attempted to play the role of a communicator and moderator between the PC and advisory and coordinating bodies and many other ministries. However, the DST's power of adjusting conflicts among ministries was not strong.

To solve this problem, the DST was given strong power of coordinating the policies and research programs among ministries by establishing 22 Science and Technology Advisory Committees (STAC) within each socioeconomic ministry, and the Inter-Sectoral STAC (IS-STAC). In 1986, the SACC was again replaced by the Science Advisory Council to the Prime Minister (SAC-PM). The STP published in 2003 emphasized increasing synergy between science (public) and industry. Nevertheless, India's innovation governance body did not change considerably.

Recently, India announced the STIP, which highlighted the needs of innovation beyond S&T. Thus, the National Innovation Council (NInC) was established. The NInC is a think-tank to discuss, analyze, and help implement strategies for innovation. It suggested the Roadmap for Innovation 2010–2020. In addition, the PC was replaced by the National Institution for Transforming India (NITI Aayog) to enhance cooperative federalism by fostering the involvement of local governments of India. Therefore, the organization of planning innovation policy changes from the PC to NITI and dedicated ministry is the same as DTS within the MST. The advisory and coordinator bodies consist of NInC, SAC-PM, STACs, and IS-STAC. Although India has endeavored to develop a holistic innovation policy that considers central and regional governments, all citizens, and all sectors, the issue of inclusiveness in the innovation policy remains.

**Figure 4: Changes in India's Innovation Policy Governance Body Over Four S&T Resolutions**




Source: Authors' creation.

## E. Malaysia

### 1. Performance of Malaysia's Innovation Policies

Table 14 shows that Malaysia, with a GDP of US$ 354 billion and GNI per capita of US$ 10,460, is an upper-middle-income country and the richest among ASEAN countries except for Singapore and Brunei. In comparison with Thailand, which belongs to the same income group, Malaysia has a better performance in innovation inputs and outputs. Particularly, its R&D expenditure as a percentage of GDP was 1.3% in 2015, which is considerably higher than that of Thailand (0.78% in 2016). Furthermore, by 1994, the private sector R&D spending overtook that of public and private sectors, which accounted for 64.5% of total R&D expenditure in 2012 and has led R&D activities since then (Suresh and Lai, 2018). Thus, Malaysia successfully transferred R&D capabilities from public institutions to private sectors, such as high-income countries (e.g., Japan and the ROK). Accordingly, it may have high potentials of moving toward a high-income country or successful catch-up phase. However, similar to India and Indonesia, the number of patent applications for nonresidents in Malaysia is five times higher than that for residents. The innovation activities of Malaysia considerably depend on foreign companies or foreigners. Malaysia has higher technology exports of 28.1% in 2017 than the ROK (26.5% in 2016), even though it presents a considerably lower achievement of patent and S&T publications than that of the ROK. Therefore, its indigenous firms' technological capabilities are relatively secured.

**Table 14: Chronological Changes in the Performance of Malaysia's Innovation Policy**

| Classification | | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Economic growth | GDP (billion US$) | 1.9 | 3.9 | 25 | 44 | 94 | 255 | 354 (34th) |
| | GDP per capita (US$) | 235 | 358 | 1,775 | 2,442 | 4,044 | 9,041 | 11,239 (60th) |
| | GNI per capita (current US$) | 240 (in 1962) | 370 | 1,790 | 2,400 | 3,460 | 8,260 | 10,460 (59th) |
| Innovation input | R&D expenditure (% of GDP) | n/a | n/a | n/a | 0.2 (in 1996) | 0.5 | 1.0 | 1.3 (in 2015) |
| | R&D expenditure (public vs. private) | n/a | n/a | n/a | n/a | n/a | 35.6[a]:64.5 (in 2012) | |
| | Researchers in R&D (per million people) | n/a | n/a | n/a | 90.1 (in 1996) | 277.0 | 1,467.5 | 2,274.1 (in 2015) |
| | Technicians in R&D (per million people) | n/a | n/a | n/a | 31.2 (in 1996) | 39.7 | 130.7 | 130.4 (in 2015) |
| Innovation output | High-technology exports (% of manufactured) | n/a | n/a | 40.6 (in 1988) | 38.2 | 59.6 | 44.5 | 28.1 (in 2017) |
| | Patent applications, residents | n/a | n/a | 8 (in 1985) | 92 | 206 | 1,231 | 1,166 (in 2017) |
| | Patent applications, nonresidents | n/a | n/a | 1,329 (in 1985) | 2,213 | 6,021 | 5,152 | 5,906 (in 2017) |
| | Scientific and technical publications | n/a | n/a | n/a | n/a | 1,741 | 11,056 | 20,331 (in 2016) |

[a] The number of 35.6% combines the R&D expenditures of higher education institutions (28.7%) and government agencies and PRIs (6.9%).
Source: Authors' creation based on the DB provided by World Bank and Suresh and Lai (2018).

## 2. Evolution of Innovation Policies

Similar to Thailand, Malaysia's innovation policy has evolved in two stages, namely, pre-industrialization (1957–1970) and industrialization and catch-up (1971–present). In the pre-industrial stage, Malaysia implemented an import-substitution industrialization policy through its First Five-year Plan, but failed. Malaysia could not focus on S&T policies because of the inter-ethnic riots caused by the disparity of wealth among many ethnic groups. In the industrialization and catch-up stage, Malaysia's innovation policy has evolved in two steps. The first step is the New Economic Policy (NEP)-driven policy (1971–1985), which focused on industrialization through the NEP and succeeded. R&D plans were available if needed by NEP; however, independent S&T policies did not exist. The second step is STI-driven policy (1986–present), which established the First National Science and Technology Policy and created a separate chapter for S&T in the Fifth Five-year Plan.

**a. Pre-industrialization phase (1957–1970)**

Current Malaysia territories consist of three parts, namely, 1) Malaya, which is now known as Peninsular Malaysia, and 2) Sarawak and 3) Sabah, which are now East Malaysia. Malaya gained independence from the British in 1957, whereas Sarawak and Sabah in 1963 and then formed the Federation in the same year. After establishing the Federation, Malaysia created the First Malaysia Plan (1966–1970) as an economic development plan to increase the standard of living in rural areas, particularly among low-income groups. It also implemented the import-substitution industrialization strategy. However, the First Malaysia Plan failed to either stem the tide of rural–urban migration or increase the income of rural families (Drabble, 2004). The trial of industrialization also lost driving force in the late 1960s because foreign investors from Britain switched their attention elsewhere, and severe inter-ethnic rioting broke out on May 13, 1969. Therefore, Malaysia did not succeed in industrialization and still relied on rubber and tin exports.

**b. Industrialization and catch-up phase (1971– present)**

**NEP-driven policy (1971−1985):** The incident on May 13 1969 was caused by the inter-ethnic economic disparities between Bumiputra (native Malays) and non-Bumiputra, especially between Malays and Chinese. The Chinese dominated most urban areas and controlled a large portion of Malaysia's economy, whereas the Malays were generally poor and occupied rural areas. The incident led to national emergency and political instability. Malaysia needed a new economic plan to solve these problems. Malaysia established the NEP, which began with the Second Malaysia Plan (1971–1975) and lasted until 1985. The major objectives of the NEP were eradication of poverty and restructuring of society via affirmative action policies. The emphasis of the NEP was slightly different according to its phase. In 1976–1980, the second phase of the NEP emphasized the private sector-driven economy, whereas its third phase (1981–1985) highlighted privatization and heavy industries (Lee and Lee, 2017). As a result, the NEP led to an increase in Bumiputera's wealth ownership from 2% in 1970 to 20.3% in 1990 (Drabble, 2004). Malaysia's economic structure also shifted from primary industry-dependent economy to secondary and tertiary industry-dependent ones, with rubber and tin accounting for 54.3% of total exports in 1970, but decreased to 4.9% in 1990. The non-resource-based manufacturing industry, such as electrical and electronics (E&E) took the lead, encouraged by tax incentives to attract FDI in free trade zones and export processing zones (OECD, 2016). In the 1980s, Malaysia's manufacturing industry expanded to heavy industries, such as steel production, machinery and equipment, petrochemical cement, and automobile, with direct intervention from the government. Malaysia achieved successful industrialization despite not yet having a distinct STI strategy framework, governance, and policy.

**STI-driven policy (1986−present)**: The First NSTP (1986–1989) and the Fifth Malaysia Plan (1986–1990) marked the beginning of STI policy in Malaysia. The NSTP presented the broad direction and framework to encourage national development based on science and innovation, scientific creativity, and awareness in general under the support of the Ministry of Science Technology and Innovation (MOSTI). The Fifth Malaysia Plan newly created the first chapter dedicated to S&T for the better institutionalization of STI policy (OECD, 2016). The Second NSTP (2002–2010) emphasized the results of STI activities on growth and competitiveness. Several industrial policies also created institutions and incentives to promote industrial R&D activities and enhance industrial R&D competences. The policies included the Industrial Master Plan (IMP1) launched in 1986 by the MITI, the Action Plan for Industrial Technology Development (APITD, 1990–2011) initiated in 1990, IMP2 (1996–2005), and IMP3 (2006–2010). In the mid-1980s and 2010, Malaysia strived hard to improve coordination and centralization of STI policies. However, the limited coordination among various STI policies (e.g., NSTP, IMP, and Five-year Malaysia Plan) resulted in many overlaps.

Table 15 describes the objectives or features of the major S&T policies from the mid-1980s to the present. From the end of the 1980s to 1990s focused on improving institutions and scientific and educational infrastructure and raising public awareness of S&T, whereas the 2000s defined quantitative objectives and concentrated resources on target sectors strategically designated. Malaysia also adopted the STI, which was reflected by the innovation concept beyond the S&T since the end of the 2000s; this concept emphasized the

enhancement of STI capabilities in the private sector, international strategic alliance, and transformation of STI governance. Malaysia has implemented the STI sector policy since 2005. Particularly, the National Biotechnology Policy was the most representative. Other STI sectoral policies included the Intellectual Property Commercialization Policy for R&D projects (2009) and the Malaysia National Green Technology Policy (2009).

**Table 15: Major STI Policies of Malaysia**

| Policy Name | Duration | Objectives/Features |
|---|---|---|
| NSTP1 | 1986–1989 | • Promote scientific and technological self-reliance<br>• Upgrade local R&D capabilities and improve scientific and educational infrastructure |
| APITD | 1990–2001 | • Strengthen institutions and support infrastructure for technological innovation<br>• Increase application and diffusion of technology<br>• Promote public awareness on the importance of S&T |
| NSTP2 | 2002–2010 | • Accelerate the development of S&T capability and national capacity for competitiveness<br>• Increase R&D expenditure to 1.5% of GDP with 60 R&D personnel per 10,000 people (neither objective was met in 2010)<br>• Support 55 initiatives in the following areas: research technological capacity, research commercialization, HR capacity, promotion of a culture for innovation, institutional framework, technology diffusion, and building competence for specialization |
| National Policy on STI | 2013–2020 | • Five foundations: 1) ensure all stakeholders accept and implement the policy; 2) provide support by building STI capacity and capabilities; 3) strengthen private sector STI capabilities; 4) ensure sound institutional and regulatory framework for the STI system; 5) infuse the belief that STI is essential for a stable, peaceful, prosperous, cohesive, and resilient society<br>• Six strategic thrusts: 1) advancing scientific and social research, development, and commercialization; 2) developing, harnessing, and intensifying talent; 3) energizing industries; 4) transforming STI governance; 5) promoting and sensitizing to STI; 6) enhancing strategic international alliances |
| STI sectoral policies: National Biotechnology Policy | 2005–2020 | • Make the biotechnology sector a key driver of economic growth, contributing 5% of GDP by 2020<br>• Implement in three phases: a capacity-building phase (2005–2010) concentrating on the establishment of advisory and implementation councils; a science-to-business phase (2011–2015) focusing on the development of local expertise and new products; and a global presence phase (2016–2020) to take Malaysian companies to the global stage |

Source: Authors' creation based on Suresh and Lai (2018).

The main policy instruments used by Malaysia's government during this period are as follows (Suresh and Lai, 2018).

**Public funding**: Numerous ministries [e.g., MOSTI (a key player of R&D public funding), Ministry of Higher Education (mainly provides funds to universities), Ministry of International Trade and Industry (mainly provides funds to SMEs), Ministry of Finance, Ministry of Energy, Green Technology and Water, and Ministry

of Agriculture and Agro-based Industry] and public agencies provide funds for the creation, research, development, and commercialization stages of R&D.

**Public project/program**: Under the policy designed by the government, various projects or programs were operated. For instance, BioValley is one of the famous public projects under the National Biotechnology Policy. For this project, the government offered cheap rent, good telecommunication infrastructure, and access to the country's rich biodiversity.

**S&T parks**: The most prominent S&T park in Malaysia is Multimedia Super Corridor (MSC) Malaysia, which was set up in 1996. S&T parks offer tax breaks, financial assistance, business networking, and easy access to government projects for foreign and local firms.

**University–industry collaboration in R&D**: All government policies stress the need for university–industry collaboration and initiatives to foster greater links between university and industry. However, collaboration with industry accounted for only 3.7%–8.7% of total university collaborative funding in 2006–2011.

**Industrial clusters**: Malaysia has developed several industrial clusters. These clusters include E&E clusters in Penang and Negeri Sembilan, information technology, creative content, technology cluster in MSC, palm oil industrial cluster in Sabah, and automotive cluster in Perak and Selangor.

**State-owned firms**: To upgrade technological capability, Malaysia's government directly participates in high-technology industries in the E&E sector by providing training and support services and by manufacturing. For instance, the Malaysian Institute of Microelectronic Systems (MIMOS) was established in 1985 to pursue research, development, and commercialization activities in microelectronics. MIMOS has two subsidiaries, namely, MIMOS Semiconductor, which provides integrated and advanced shared facilities for the E&E sector, and MIMOS Technology Solutions, which generates new technology ventures through innovation, investment, and transfer of technology.

### 3. Innovation Policy Governance

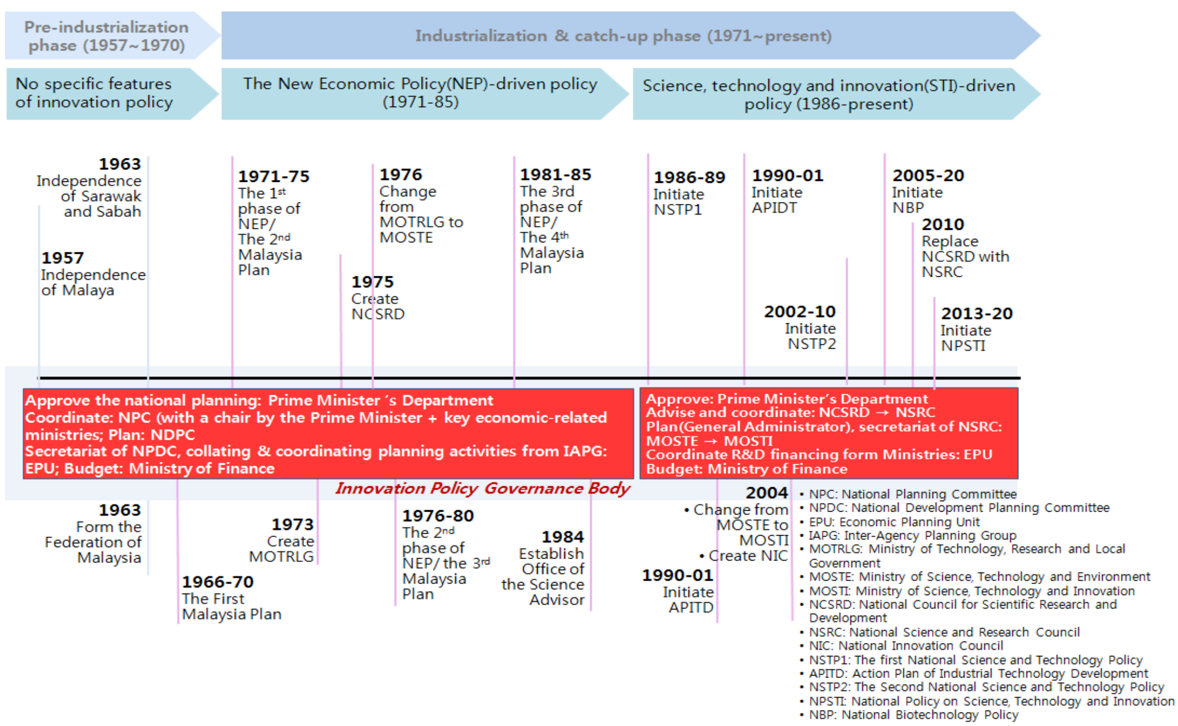
Malaysia did not have a distinct STI policy until the mid-1980s. Although the first ministry, dedicated to STI matters was established in 1973 (that is, the Ministry of Technology, Research, and Local Government, (formerly MOSTI), its roles and influences were limited.

**From independence to the mid-1980s**, Malaysia focused on formulating and implementing national development plans, such as the Five-year Malaysia Plan and NEP. These national development plans, especially the Five-year Malaysia Plan [the 11th Malaysia Plan (2016–2020) is currently underway], remain until now. The governance body for these national development plans consisted of the Prime Minister's Department, the National Planning Committee (NPC), the National Development Planning Committee (NDPC), the Economic Planning Unit (EPU), and the MOF. The EPU was under the Ministry of Economic Affairs and plays key roles in development planning. 1) It helped the NDPC formulate a reasonable and right plan as a secretariat and 2) collated and coordinated many planning activities among ministries by referring proposals suggested by the Inter-agency Planning Groups. The NDPC formulated plans by referring to EPU's works. The NPC, chaired by the Prime Minister and comprised ministers from key economic-related ministries (e.g., finance, international trade, and domestic trade), performed high-level coordination among ministries. Last, plans were approved by the Prime Minister's department, and the power of budget allocation was exercised by the MOF.

**Since the mid-1980s**, MOSTI's role and power have become stronger because Malaysia began to develop various STI policies. In establishing STI policy, the MOSTI takes the role which the EPU plays in national development planning. The MOSTI is the general administrator of STI policy. It oversees several agencies, R&D centers and institutions, and government-funded enterprises and runs R&D support programs directly or

indirectly. MOSTI is also the secretariat of the National Council for Scientific Research and Development (NCSRD, formerly National Science and Research Council). The NCSRD serves as a high-level body of coordination among ministries, as reflected by the works of the MOSTI. STI policies are approved by the Prime Minister's department and budgeted by the Ministry of Finance, which is similar to the National Development Plan. Since an independent STI policy was implemented, Malaysia sought to reduce the overlap of STI policies among ministries by handing over the control of STI policies among ministries to the MOSTI, although it has not succeeded yet until now. Not only MOSTI but the Ministry of Higher Education, MITI, Ministry of Energy, Green Technology and Water, National Innovation Agency of Malaysia, and other ministries that have PRIs or relevant government-linked firms under their jurisdiction are also involved in planning and implementing their own STI policies and R&D activities. Thus, the EPU coordinates R&D financing from various ministries via reviewing its STI budget applications.

**Figure 5: Changes in Malaysia's Innovation Policy Governance Body**




Source: Authors' creation.

## F. Thailand

### 1. Performance of Innovation Policies

Thailand has performed well in many fields since the 1970s and has grown to become the second-largest, upper-middle-income country in Southeast Asia. The Thai economy has undergone structural changes in the previous decades, with successful reforms to promote investment and openness since the 1960s. Quantitative reallocations of labor and capital inputs were made from agriculture to manufacturing and services. Agriculture remains a backbone industry, employing 30.7% of the workforce and contributing approximately 8.1% to GDP. Thai's total R&D spending soared to 0.78% of GDP, and private investments accounted for 76.25% of the total R&D expenditure in 2016. Exports accounted for 66.8% of Thailand's GDP in 2018; whereas hard disk drives, auto parts, and textile manufacturing accounted for 77.5% of total exports. High-technology exports accounted for 21.5% of total manufactured exports in 2016. Given economic growth, society has progressed, and poverty

has plunged from 60% in 1990 to 7% at present. However, creating quality formal jobs and regional imbalances remain pressing challenges.

**Table 16: Chronological Changes in the Performance of Thailand's Innovation Policy**

| Classification | | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Economic growth | GDP (billion US$) | 2.8 | 7.1 | 32 | 85 | 126 | 341 | 505 (25th) |
| | GDP per capita (US$) | 100 | 192 | 683 | 1,509 | 2,008 | 5,076 | 7,274 (80th) |
| | GNI per capita (US$) | 110 (in 1962) | 210 | 710 | 1,490 | 1,980 | 4,580 | 6,610 (78th) |
| Innovation input | R&D expenditure (% of GDP) | n/a | n/a | n/a | 0.12 (in 1996) | 0.24 | 0.36 (in 2011) | 0.78 (in 2016) |
| | R&D expenditure (public vs. private) | | | | | | 44:56 (in 2011) | 24:76 (in 2016) |
| | Researchers in R&D (per million people) | n/a | n/a | n/a | 100 (in 1996) | 279 (in 2001) | 538 (in 2011) | 1,210 (in 2016) |
| | Technicians in R&D (per million people) | n/a | n/a | n/a | 38.3 (in 1996) | 111.9 (in 2001) | 167.5 (in 2011) | 320.3 (in 2016) |
| Innovation output | High-technology exports (% of manufactured exports) | n/a | n/a | n/a | n/a | 27.8 (in 2007) | 26.2 | 23.3 |
| | Patent applications, residents | n/a | n/a | 13 | 73 | 561 | 1,214 | 979 (in 2017) |
| | Patent applications, Nonresidents | n/a | n/a | 202 | 1,867 | 4,488 | 723 | 6,886 (in 2017) |
| | No. of scientific and technical publications | n/a | n/a | n/a | n/a | 2,260 (in 2003) | 6,811 | 9,582 (in 2016) |

Source: Authors' creation based on the DB provided by World Bank and UNESCO UIS.

## 2. Evolution of Innovation Policies

The evolution of Thailand's innovation policies can be divided into two stages, namely, pre-industrialization and industrialization and catching up." In the pre-industrial stage, innovation activities were inactive due to political instability and the Second World War. In the 1960s, import substitution policy was the focus of strategy. From the early 1970s, it shifted to an export-oriented strategy. In the early stages of industrialization in Thailand, productivity gains were achieved through labor-intensive manufacturing by reallocating under-utilized rural labor based on capital accumulation and import technology through FDI. Export-led growth was achieved in the 1980s while reforming local industry structures and strengthening competitiveness, encouraging exports of manufactured products, and providing selective macro and microlevel incentives. In the 1990s, the government launched the neo-populist policy, which resembled that of Latin America in the 1980s and 1990s. In the 2000s, human-centered innovation policy was established to escape from the middle-income trap. Now, Thailand has a strategy that focuses on improving productivity without being entrenched in capital and labor quantitative inputs.

### a. Pre-industrialization phase (1938–1969)

In the early 1940s, Japanese imperial forces swept from Burma to Indonesia, integrating all colonial territory into the Greater East Asian Empire system. Thailand, a pro-Japanese government, was an ally of Japan and had never been a colony of other countries explicitly. Thailand produced agricultural products in exchange of Japanese manufacturing products. This relationship avoided devastation, such as in Burma and the Philippines, and anti-colonial violence, such as in Indonesia, France, and Indochina, due to Japan's defeat in 1945. In 1950, Thailand's GDP per capita nearly caught up with pre-war levels; however, the economic recovery in many other Asian regions took considerably longer, and the exchange rates of the many parts of the regions were overvalued. Despite high inflation rates, GDP per capita increased slightly from 1938 to 1954. Since 1945, Thailand has been politically unstable. The influence of France and the United Kingdom was greatly diminished, whereas the influence of the US increased, the Communist Party occupied the PRC, and the influence of the indigenous Communist Party in Southeast Asia became prominent.

In the 1960s, 80% of the population in Thailand lived in rural areas, and agriculture was the common source of people's livelihood. The main export items were rice, rubber, and timber. Political instability was divided into communism and capitalism in Southeast Asia, and the Thai people lacked the primary necessities. Therefore, national security and economic stability were the first and foremost development goals (First and Second National Economic and Social Development Plans). In this context, the economic development plan focused on the construction of basic infrastructure (e.g., roads, ports, dams, and power plants) and project-based development plans were conducted through external loans. Import-substitution industrialization was the major policy tool for economic and social development.

### b. Industrialization and catch-up phase (1970s–present)

#### Early industrialization phase (1970s–1996): Rapid growth

In the 1970s, economic imbalances were detected. The innovation policies focused on economic growth and stability for social justice and fair distribution of income. Thailand expanded the school and medical facilities and promoted primary health care (Third and Fourth National Economic and Social Development Plans). In 1979, the Ministry of Science, Technology, and Energy was established, and the Fifth National Economic and Social Development Plan (1982–1986) began to highlight the importance of S&T. Industrial policies in Thailand were limited to functional intervention, such as promoting infrastructure building, general education, and export promotion. No explicit performance-based criteria, such as technological upgrade target, provided state incentives, such as in the ROK or Japan. Since the 1960s, policy and resource allocation for building industrial technology development capabilities focused on the capabilities and resources of scientific, technological, and training institutions. Policy measures or resource allocations for strengthening the enterprises own technology learning, technology capabilities, and innovation activities were negligible. The concept of innovation remained not systemically appreciated.

In the 1980s, Thailand finally earned political stability; however, problems, such as oil price crisis, national debt crisis, trade deficit, and global economic downturn, arose. Poverty reached 20.6% of the population in 1981. The development plan focused on inter-sectoral coordination for poverty eradication and improving the quality of life of the poor. Public spending was limited to 17%–19% of GDP, and a cap on external borrowing was set. Structural reforms, campaigns for domestic product use, and export promotion were aggressively promoted (Fifth and sixth National Economic and Social Development Plans).

**Table 17: Evolution of Thailand's Innovation Policies during Industrialization and Catch-Up Phase**

| | | |
|---|---|---|
| Early industrialization phase | 1970s | • Export-oriented policies and expanding school and healthcare facilities |
| | 1980s | • Inter-sectoral coordination for poverty eradication and improving the quality of life of the poor |
| | Early 1990s | • Holistic approach for innovation and SME Promotion Master Plan |
| Crisis and welfare (populism) trap | 1996–2011 | • Policies on enabling Thailand to move out of a middle-income trapped economy<br>• First SME Promotion Master Plan (2002–2006)<br>• Second SME Promotion Master Plan (2007–2011) |
| Thailand 4.0 | 2012–2021 | • Thailand 4.0<br>• Third SME Promotion Master Plan with national entrepreneurship policy (2012–2016)<br>• Use of public mega investment projects and government procurement to stimulate innovation in strategic areas (e.g., rail system and water management; 2014–present)<br>• Digital economy transition |

Source: Authors' creation from synthesis of literature reviews.

**Crisis and welfare (populism) trap: Limit of strategies (1997–2011)**

In the early 1990s, Thailand was called the "fifth tiger." Different from other developing countries, it succeeded in reforming its economic structure, emerging as a model for rapid economic growth and diversification beyond agriculture. In 1993, it was one of eight Asian economies included in Asia's Miracle Report published by the World Bank; however, severe economic problems began to arise. Real wages rose faster than the education level of the labor force, and many export-oriented firms began to migrate to the PRC, Viet Nam, and South Asia, where labor was cheaper and more educated. Bangkok International Banking Facility was established to make Bangkok a regional financial center. However, in reality, most of the foreign money flowed into urban real estate. In late 1996, baht was devalued, the currency collapsed in early July 1997, and real GDP continued to decline. Social problems, such as changing demographics, changing disease patterns, increasing women's social involvement or labor, environmental pollution, AIDS, and drug abuse, also emerged. The National Economic and Social Development Plan focused on quality of life and addressing regional imbalances. The Eighth National Development Plan was not a blueprint but a holistic approach in which people and socio and socioeconomic environments were interconnected. The Thaksin administration in the 1990s launched the neo-populist policy, followed the national SME promotion policy along with national financial, medical, and social reforms. Ironically, industries became increasingly critical in terms of contribution to GDP and export. In 1997, R&D expenditure for agriculture sciences was 42%, whereas that for engineering and applied sciences was only 6.94% of the total government expenditure on R&D. In the 2000s, HM King's policy focused on people-centered development, and efforts to escape the middle-income trap continued. In 2008, the National Science, Technology, and Innovation Act was enacted as the foundation for Thailand's STI policy for the 21st century.

**Efforts for revitalizing catch-up: Thailand 4.0 (2012–present)**

The Eleventh and Twelfth National Economic and Social Development Plans include a fair society, lifelong learning-based human capital development, strengthening agri-food and energy industries, reforming economic structures, strengthening regional connectivity, and sustainable natural resource and environmental management strategies. Thailand now has a strategy that focuses on improving productivity without being entrenched in capital and labor quantitative inputs. Thailand's Twelfth plan aims at an annual 2.5% increase in

labor productivity and total factor productivity based on quality human capital development, regulatory reform, and infrastructure development.

In April 2012, the Cabinet approved a 10-year National STI Master Plan (2012–2021), which provides mechanisms for enriching Thailand's innovation system at all levels, from national to regional and local. In this plan, innovation was systematically introduced for the first time. At the foundation, the Master Plan states that knowledgeable and skilled human capital, along with sufficient scientific and technological infrastructure and enabling factors, are vital for the creation of a thriving innovation system. Therefore, strategies and measures are mapped out to develop these vital factors, resulting in human capital development programs. The vision is green innovation for quality society and sustainable economic growth while controlling geopolitical and climate change. According to the Master Plan, strategic economic sectors are rice and rice products, bio-based energy, rubber and rubber products, processed food, E&E, automotive and parts, plastics and petrochemicals, fashion (textiles, jewelry, and leather), tourism, logistics, construction and related services, and creative and digital contents. In 2016, only 38% of the total R&D expenditure came from private investment. By 2021, Thailand aims to increase its private R&D investment to 70%.

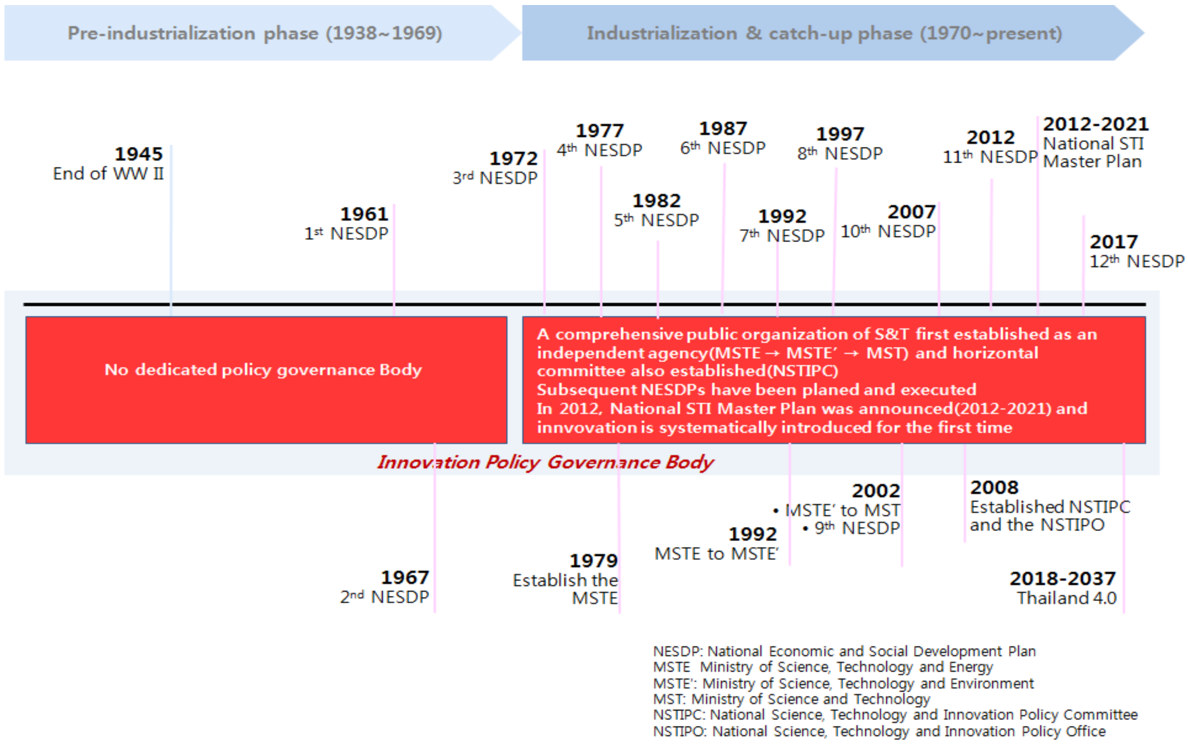
In October 2018, national strategy Thailand 4.0 was launched with an announcement officially published in the Royal Gazette (Thai Embassy, 2018). Thailand 4.0, an ambitious strategy spanning 20 years, was designed to promote and support innovation, creativity, R&D, advanced technology, and green technology. Even before the official announcement, the government has been promoting the strategy for more than two years, and investors have been responding.

Several global companies have pledged to participate in the Eastern Economic Corridor, the three most advanced development zones near Bangkok (i.e., Rayong, Choburi, and Chachangsao), which will be showcased for Thailand 4.0. The government and private companies are already building the advanced infrastructure needed to turn EEC's vision into reality. Thailand 4.0 emphasizes "security, wealth, and sustainability." The kingdom is already classified as an upper-middle-income country. Nevertheless, policymakers believe that the strategy will allow them to earn a high-income country status.

**3. Innovation Policy Governance**

The Ministry of Science, Technology and Energy(MSTE), which is the main entity for developing STI policies, was established in 1979. The Fifth National Economic and Social Development Plan began to emphasize the importance of S&T.

**Figure 6: Changes in Thailand's STI Governance System from 1979 to Present**

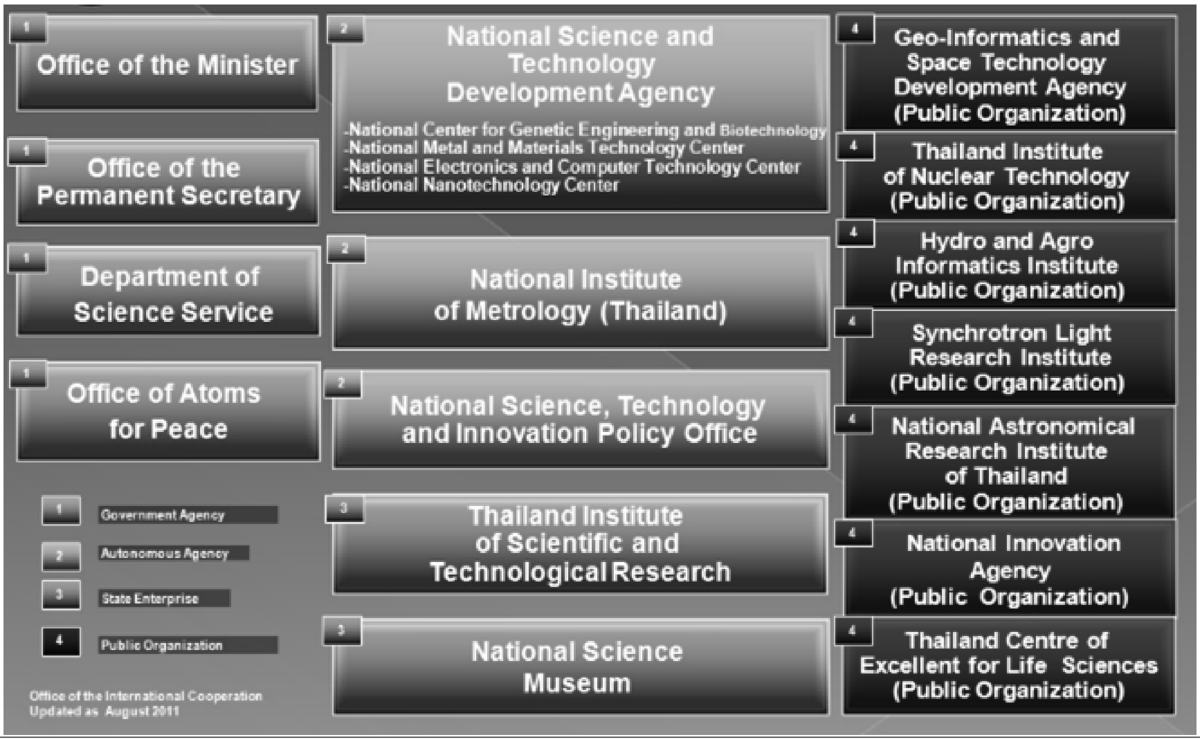



Source: Authors' creation.

In 1992, the MSTE was changed to the Ministry of Science, Technology, and Environment (MSTE′). MSTE′ was responsible for formulating national policy on science, technology, environment, and energy and implementing these policies efficiently and in coordination to bring about the most socioeconomic benefits and national stability. MSTE′'s responsibilities on S&T, environment, and energy were not directly related to achieving the objectives of national development in each field. MSTE′ should structure the administration to be composed of four ministries, namely, Ministry of Natural Resources and Environment, Ministry of Energy, Ministry of Information and Communication Technology, and MSTE′, to solve the aforementioned problem. From October 2002, according to the Bureaucratic Restructuring Act, MSTE′ changed its name to Ministry of Science and Technology(MST). The MST is presently tasked with forwarding the policy and strategic plan for STI and seeing to its effective and substantive implementation in terms of R&D, as well as creating cooperative mechanisms among all sectors of society to promote economic benefits and enhance the quality of life. Under the vision of "excelling as the steward or main organization in the development of STI," MST aims to create and enrich the intellect of Thai society in a manner that will support economic and social development and sustainable competitiveness. A total of 16 crucial supporting agencies will assist in this respect, namely, government agencies, autonomous agencies, state enterprises, and public organizations under the structure of the MST. Several other related ministries are the Ministries of Education, ICT, Industry, Commerce, Agriculture, and Health. Their ministers consist of the National STI Policy Committee, chaired by the Prime Minister, and assisted by several independent experts and high-level civil servants since February 2008. To unify STI commitments among public agencies and strengthen the collaboration with and among the private sector, academics, and research institutes, the National Science Technology and Innovation Policy Office, an autonomous public agency under the National STI Policy Committee chaired by the Prime Minister, was established in 2008. The governance structure of STI policy operations is somewhat fragmented, complex, and partially overlapped. Furthermore, some essential parts, including strategic drivers are missing or often misunderstood. The governance system tends to elaborate plans consisting of extensive lists of actions without

prioritization, monitoring, and evaluation. The business sector is insufficiently involved in policy elaboration and strategic decision making.

**Figure 7: Current STI Governance System of the MoST, Thailand**




Source: https://www.mhesi.go.th/main/en/ministry-of-science-and-technology/organization-chart, updated in July 2015.

## G. Indonesia

### 1. Performance of Innovation Policies

Table 18 shows that Indonesia has rapidly grown to be the 16th largest economy and nearly one of the upper-middle-income countries (See Footnote 1). However, it presents a seriously poor performance in innovation input and output. Particularly, its R&D expenditure as a percentage of GDP was 0.09% in 2018, which is one of the lowest rates among other ASEAN countries, such as Malaysia (1.30% in 2015), Thailand (0.78% in 2016), and Viet Nam (0.44% in 2015). Nearly 85% of the total R&D expenditure was spent by the public rather than private sector. The current indigenous firms' R&D capabilities are extremely low to enter the group of high-income country through successful catch-up. Similar to India, the number of patent applications by nonresidents was 10 times in 2010 and 4 times in 2017 of that by residents. This finding indicates that Indonesia's innovation has considerably relied on foreign firms or foreigners.

**Table 18: Chronological Changes in the Performance of Indonesia's Innovation Policy**

| Classification | | 1967 | 1970 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Economic growth | GDP (billion US$) | 5.7 | 9.2 | 73 | 106 | 165 | 755 | 1,042 (16th) |
| | GDP per capita (US$) | 54 | 80 | 492 | 585 | 780 | 3,122 | 3,893 (115th) |

| Classification | | 1967 | 1970 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|---|
| | GNI per capita (US$) | 70 (1969) | 80 | 470 | 560 | 580 | 2,530 | 3,840 (111th) |
| Innovation input | R&D expenditure (% of GDP) | n/a | n/a | n/a | n/a | 0.07 | 0.08 (in 2009) | 0.09 (in 2013) |
| | R&D expenditure (public vs. private) | n/a | n/a | n/a | n/a | 84.5: 14.7 (2001–2006) Other sources: 0.8% | | n/a |
| | Researchers in R&D (per million people) | n/a | n/a | n/a | n/a | 212.7 | 89.2 (in 2009) | n/a |
| Innovation output | High-technology exports (% of manufactured) | n/a | n/a | 1.5 (in 1989) | 1.6 | 16.4 | 9.8 | 5.7 (in 2017) |
| | Patent applications, residents | n/a | n/a | 5 | 34 | 157 | 508 | 2,271 (in 2017) |
| | Patent applications, nonresidents | n/a | n/a | 475 | 1,280 | 3,733 | 5,122 | 7,032 (in 2017) |
| | Scientific and technical publications | n/a | n/a | n/a | n/a | 359 (in 2003) | 1,344 | 7,728 (in 2016) |

Source: Authors' creation based on the DB provided by World Bank, Pappiptek LIPI (2009), and OECD (2010).

## 2. Evolution of Innovation Policies

Similar to India, Indonesia's innovation policy evolved in two stages, namely, pre-industrialization phase and industrialization and catch-up phase. In the pre-industrialization stage (1945–1966), Indonesia suffered from painful economic growth due to political instability and inadequate economic policies. It could not afford to pay attention to S&T plans, except for human resource development. In the industrialization and catch-up phase (1967–present), Indonesia's innovation policy has two stages. The first stage is industrialization-oriented policy (1967–1998) along with *Repelita*, Indonesia's Five-year Plan. The second is the NIS-strengthen policy, which set up the legal framework that developed various development plans.

### a. Pre-industrialization phase (1945–1966)

Since August 1945, when Japan surrendered to Allied Forces, Indonesia had to recover from the economic order disturbed and dislocated by Japanese occupation (1942–1945) and the Indonesian National Revolution (1945–1949) against the Dutch re-colonization efforts. Economic growth was minimal from 1950 to 1957 (Touwen, 2008). In 1958–1965, economic growth rates dwindled due to political instability and inappropriate economic policy measures. Sukarno, the first president after independence, aimed at self-sufficiency and import substitution. Hence, the government eliminated all foreign economic control in the private sectors in 1957–1958, which resulted in exchange rate problems and the absence of foreign capital being detrimental to economic development. Indonesia had not yet entered the industrialization process because its economy leaned toward the agricultural sector (which accounted for 56% of GDP in 1965) for the aim of agricultural self-sufficiency. Given its agricultural-oriented industrial structure, Indonesia's government was unaware of the need for S&T. Therefore, Indonesia's few S&T policies focused on the development of human resources, such as the establishment of various colleges and scholarships for Indonesian students to be sent to India or Australia to gain knowledge and experiences.

**b. Industrialization and catch-up (1967–present)**

**Industrialization-oriented policy (1967–1998)**: In the New Order era (1967–1998) when Suharto took power from Sukarno, industrial sector development policy was prioritized to solve the serious economic downturn left by the previous administration called the Old Order era. The government used six times of the Five-year Development Plan (hereinafter called *Repelita*) as a substantial political means. The *Repelita* was based on the State Policy Guidelines (GBHN), which are the state guidelines regarding the implementation of the state in broad outlines as a statement of the will of the people in a comprehensive and integrated manner, as determined by the Peoples' Consultative Assembly (MPR). The first *Repelita*, which started in 1969, was a manifestation of formal industrial policies. Since 1969, the six *Repelitas* proceeded with industrialization according to the following systematic sequence: *Repelita* I (1969–1974) aimed at industries that support the agriculture sector; *Repelita* II (1974–1979) targeted industries processing raw materials to produce standard materials; *Repelita* III (1979–1984) targeted industries processing standard materials to produce finished goods; and *Repelitas* IV (1984–1989),V (1989–1994), and VI (1994–1998) aimed at industries producing machines (Tambunan, 2006). For successful industrialization, Indonesia's government leveraged the following policy instruments: 1) attraction of FDI, 2) international trade liberalization through deregulation over export and import, 3) reduction of subsidy for state-owned firms, 4) various fiscal incentives for priority industries, 5) direct involvement as the main producer by being a state-owned firm or indirect involvement as a major shareholder of state-owned firms, and 6) gradual shift from import substitution to export promotion. As a result, Indonesia succeeded in industrial structure transformation for these three decades and achieved remarkable economic growth. The share of agriculture in GDP decreased from 42% in 1976–1970 to 21.8% in 1986–1996, whereas the share of industries in GDP increased from 11.9% to 22.8% in the same period. Real income per capita increased more than 10 times from US$ 70 in 1969 to US$ 1,100 in 1997 (Tambunam, 2006).

**NIS-strengthen policy (1998–present)**: The Asian financial crisis of 1997 revealed the weaknesses of Indonesia's economy that were hidden during Suharto's long-term rule and were not easily overcome. This situation triggered public dissatisfaction with the Suharto regime and demanded for direct presidential elections, which eventually brought up the four amendments of the 1945 Constitution of Republic Indonesia from 1999 to 2002. Indonesia first developed S&T policies and support programs within the legal framework by enacting Law No. 18 (2002) based on the Fourth Amendment of Constitution. This law covered the National System of Research, Development, and Application of Science and Technology (Sinas Iptek), provided regulation of resources in building an NIS, and became the guideline for S&T actors which consist of universities, R&D institutes, enterprises, and supporting institutes (Putera et al., 2014).

Two years later, Indonesia enacted another important, Law No. 25 (2004), which stipulated the National Development Planning System. The main reason for this enactment was the abolishment of the GBHN after the effectuation of the amendments of the 1945 Constitution. The National Development Planning System based on Law No. 25 (2004) replaced the GBHN. The law encompassed the legal basis of development planning of central (national) and regional governments in the long term (20 years, RPJP), medium term (5 years, RPJM), and annual term (1 year, RKP). At present, the RPJP (2005–2025) is divided into four RPJMs: first (2005–2009), second (2010–2014), third (2015–2019), and fourth (2020–2024). The first and the second RPJMs have already been implemented, and the third RPJM is in effect now. The RPJM also has to include the plan of *Sinas Iptek* (NIS). The RPJP and RPJM seemingly play a similar role as the GBHN and *Repelita* in the New Order era, respectively; however, they are also different, such that they provide plans for the S&T field separately from economic and other fields and plans dedicated to strengthening the NIS. Table 19 shows the different aims of the four RPJMs.

**Table 19: Different Aims of Four RPJMs Related to S&T**

| First RPJM (2005–2009) | Second RPJM (2010–2014) | Third RPJM (2015–2019) | Fourth RPJM (2020–2024) |
|---|---|---|---|
| • Increased quality of human resources, especially in the | • Continued the first RPJM | • Continue the second RPJM<br>• Prioritize STI | • Continue the third RPJM |

| | | | |
|---|---|---|---|
| marine sector that is supported by the development of S&T<br>• Signified Indonesian man and society as S&T-oriented character | • Enhanced the quality of human resources, including the development of the capability in S&T<br>• Increased national competitiveness by strengthening the manufacturing industry, along with agriculture, marine, and other natural resources | | • Focus on S&T the application<br>• Create an Indonesian S&T portal |

Source: Authors' creation based on BAPPENAS-Indonesian Ministry of National Development Planning (2007).

In 2011, Indonesia also embarked on a national innovation strategy called "Master Plan for the Acceleration and Expansion of Indonesian Economic Development (MP3EI, 2011–2025)," which was implemented by the Ministry of Research and Technology (RISTEK), now Ministry of Research, Technology and Higher Education (RISTEKDIKTI). The MP3EI aims to for Indonesia become the world's 10th largest economy by 2025, as well as strengthen the Indonesian NIS (SEA-EU-NET website). To achieve this goal, Indonesia creates six economic corridors around the representative islands, designating the strategic industries, and creates a value of $3.5 trillion through six economic corridors. The representative innovation policy instruments used by Indonesia since the Asian Financial Crisis in 1997 through the Sinans Iptek, RPJP, RPJM, RPK, and MP3EI are summarized as follows (Damuri et al., 2018).

First, **providing funds and incentives for R&D**: Facilitating increased R&D in universities and firms includes direct funding; noncompetitive R&D funding to public universities; competitive research grants; tax deductions for R&D; technology insurance schemes; establishment of government R&D institutions; R&D subsidies for firms; and R&D partnership among the government, universities, and industries.

Second, **creating platforms to trigger, facilitate, and diffuse innovation**: Most of the platforms had been established in the last 5–10 years and consisted of the Business Innovation Center, technology transfer office, the Techno Park, science parks, industrial clusters, special economic zones, entrepreneurship centers and incubators, testing and certification centers, and various ad hoc collaborations with foreign firms to set up innovation or training centers.

Third, **building capacity and improving absorptive capacity**: This policy includes most of the government's in-house training programs, exchange programs for local engineers under government-to-government arrangements, research training in and by public universities, scholarship programs for Indonesian students to study abroad, and general education and S&T development policies.

The Indonesian government established and implemented almost all innovation policy instruments. However, its performance is extremely slow to achieve the goal. For instance, the MP3EI has targeted $4,300 billion of GDP and US$ 14,900 of GNI per capita in 2025. However, as of 2018, GDP is $1,042 billion, and GNI per capita is less than $4,000. The goal is apparently not easy to achieve in the six remaining years.

### 3. Innovation Policy Governance

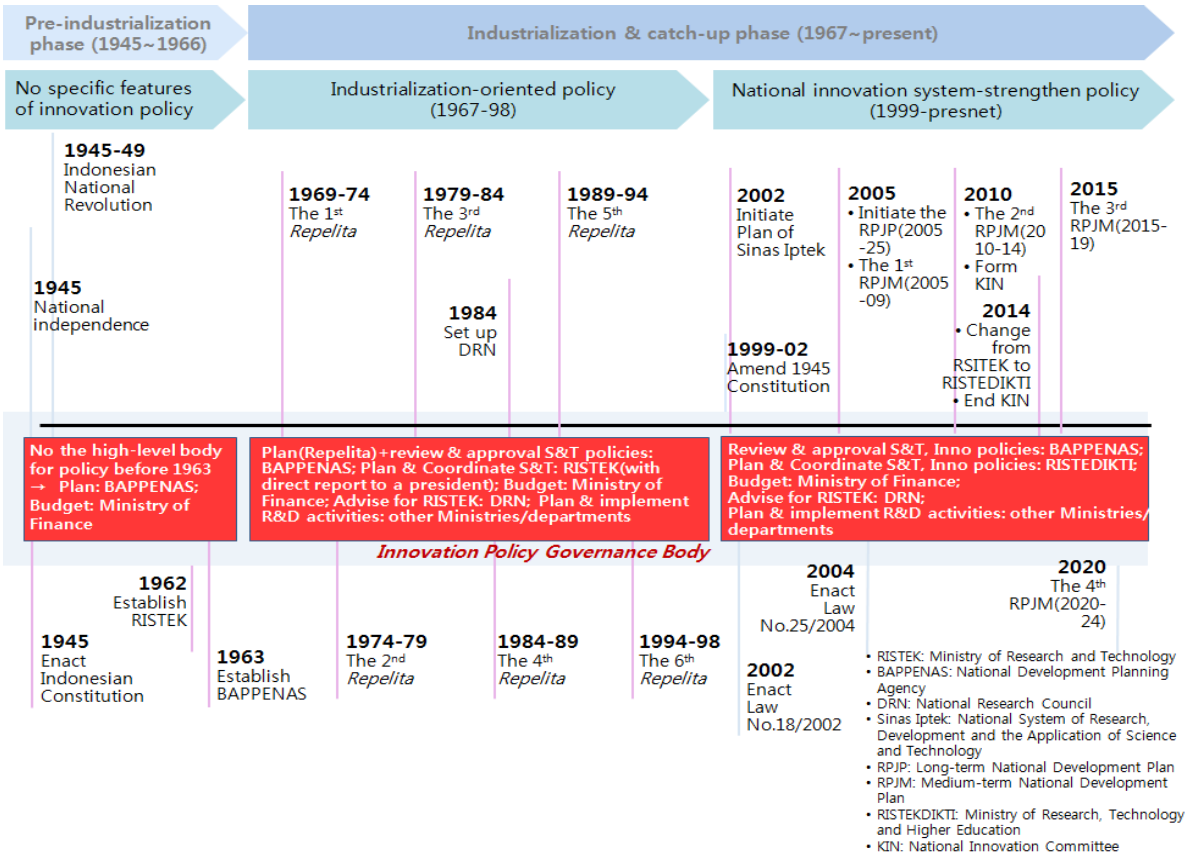
Figure 8 shows that Indonesia's innovation policy governance body has undergone change thrice. **In the pre-industrialization phase**, Indonesia established no particular S&T and innovation policies, as well as no high-level body to plan and coordinate policies at the national level due to political and economic instability. Since the BAPPENAS was established in 1963, all National Development Plans had been created around the

BAPPENAS; however, its planning power was not strong during that time. In 1962, the RISTEK, the ministry dedicated to S&T, was established, but was under the name of the Ministry of National Research Affairs. Therefore, the RISTEK had a limited role and did not include all S&T policies. The roles related to budgets of all national plans had been undertaken by the Ministry of Finance since then.

**During the New Order era**, the *Repelita*, the Five-year National Development Plan, was designed six times around the BAPPENAS. It focused on industrialization policies rather than S&T policies for a successful transition from agricultural to industrial society. No independent S&T and innovation policy was included in the *Repelita*. However, the ministries/departments independently planned and executed more R&D activities than in pre-industrialization phase. Therefore, the RISTEK was responsible for planning and coordinating all R&D activities across ministries/departments, prioritizing them, establishing necessary S&T policies, and reporting directly to the President. Since then, the RISTEK has been the key planner and coordinator of S&T policies in Indonesia. The RISTEK submits its S&T policies determined through its coordination with ministries/departments to the BAPPENAS. The BAPPENAS approves the RISTEK's proposed S&T policies after reviewing whether they are consistent with *Repelita*. BAPPENAS's roles of review and approval of S&T policies remain until now. Lastly, the National Research Council (DRN) established in 1984 has been providing advice for the RISTEK.

**From 1998 until now**, the largest change is the enactment of Law No. 18 (2000) and Law No. 25 (2004). These laws enabled S&T and innovation policies to be included within the legal framework, which resulted in ensuring independence from other national development plans and increased investment from the government. This period also differs, such that it emphasizes the NIS over S&T. Thus, the National Innovation Committee (KIN) was established by the President in 2010 as an advisory organization but was abolished in 2014. During this period, the Indonesian innovation policy governance body did not change considerably compared with the previous stage. The major change is that BAPPENAS plans the Long-term (RPJP), Medium-term (RPJM), and Annual-term (RKP) National Development Plan instead of *Repelita*, and the RPJM should reflect policies related to the NIS. Moreover, in 2014, RISTEK became the Ministry of Research, Technology, and Higher Education (RISTEDIKTI) by merging the Directorate General of Higher Education and expanding its roles to the higher education fields. Although the RISTEDIKTI is the key coordinator and planner for S&T and innovation policies, a strong high-level coordinating body is still needed because many ministries, departments, and Agencies have been planning and executing their R&D activities individually.

**Figure 8: Changes in Indonesia's Innovation Policy Governance Body**




Source: Authors' creation.

## H. People's Republic of Bangladesh

### 1. Performance of Innovation Policies

Bangladesh is the world's 41st largest economy in nominal terms and 32nd largest by purchasing power parity. Table 20 shows that most -economic gains have taken place since the early 1990s, when the introduction of wide-ranging economic reforms coincided with a transition to democracy. The growth of per capita GDP was slow in the 1980s (with an annual average of 1.6%) but accelerated to 3% in the 1990s (approximately 6% in 2006) and more than 7% in the recent period. In terms of innovation input, R&D expenditure in GDP was 0.027% from 2004 to 2005. In terms of innovation output, the number of S&T technical publications increased rapidly, doubling from 1,200 in 1999 to 2,546 in 2018.

**Table 20: Chronological Changes in the Performance of Bangladesh's Innovation Policy**

| Classification | | 1972 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|
| Economic Growth | GDP (billion US$) | 6.3 | 18 | 31 | 53 | 115 | 249 (41st) |
| | GDP growth (%) | -14.0 | 0.8 | 5.6 | 5.3 | 5.6 | 7.9 |
| | GDP per capita (US$) | 93 | 222.63 | 297.57 | 405.60 | 757.67 | 1,675 (147th) |

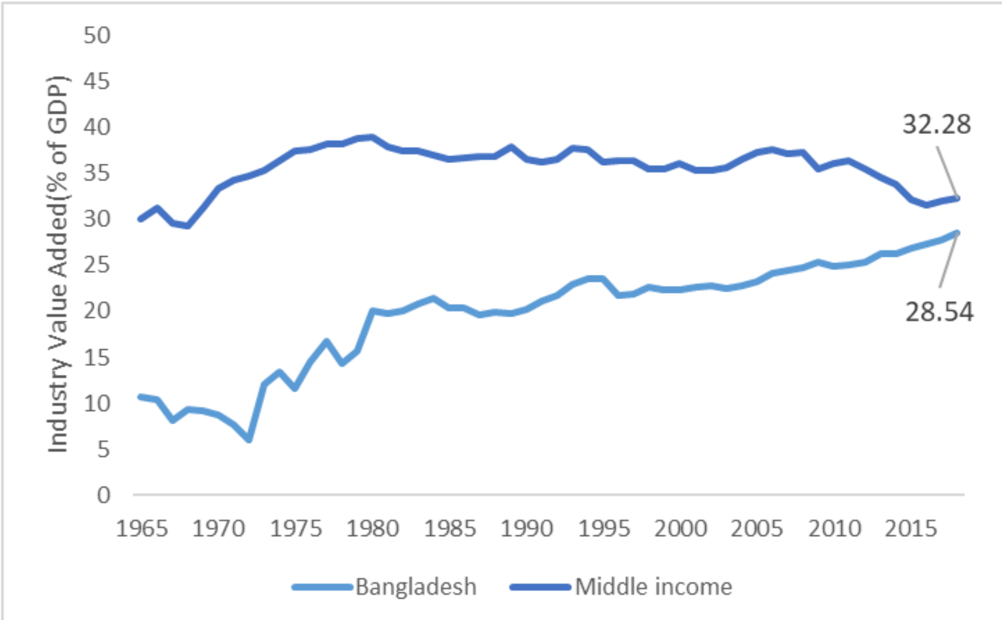
| Classification | | 1972 | 1980 | 1990 | 2000 | 2010 | 2018 |
|---|---|---|---|---|---|---|---|
| | GNI per capita (US$) | 120 (in 1973) | 230 | 320 | 440 | 800 | 1,750 (141st) |
| Innovation Input | R&D expenditure (% of GDP) | n/a | n/a | 0.01 (1994–1995) | 0.027 (2004–2005) | n/a | n/a |
| | R&D expenditure (public vs. private) | n/a | n/a | n/a | n/a | n/a | n/a |
| | Researcher in R&D (per million people) | n/a | n/a | n/a | n/a | n/a | n/a |
| | Technicians in R&D (per million people) | n/a | n/a | n/a | n/a | n/a | n/a |
| | Public institute (No. of GRIs) | 5 | 14 | 39 | 56 | 84 | 124 |
| Innovation Output | High-technology exports (% of manufactured exports) | n/a | n/a | 0.48 | 0.21 | 0.18 | 0.38 |
| | Patent applications, residents | 19 | 34 | 32 | 70 | 66 | 61 |
| | Patent applications, nonresidents | n/a | 34 | 32 | 70 | 66 | 61 |
| | No. of scientific and technical publications | n/a | n/a | n/a | 1,220 (in 1999) | 1,970 (in 2010) | 2,546 (in 2018) |

Source: Authors' creation based on the DB provided by World Bank and Hossain et al. (2012).

## 2. Evolution of Innovation Policies

Bangladesh became independent from Pakistan in 1971 after the end of the third Indo–Pakistan War. Bangladesh's government was unsettled for about 20 years after the independence until the civil government took office in 1990. Even in unstable political situations, Bangladesh undertook different initiatives for innovation policies. These policies can be summarized in two phases. In the pre-industrialization phase, Bangladesh focused on the nationalization of industry and limited private and foreign investments. This policy was succeeded by Pakistan's economic policy. In the industrialization phase, Bangladesh concentrated on developing industrialized society through different governmental incentives and privatization. Figure 9 shows the proportion of value added, excluding agriculture and mining, to the total GDP, reflecting a steep rise from the early 1970s. However, the innovation policies of Bangladesh did not have a considerable effect due to political instability. The government introduced a centralized initiative to promote citizen-centric innovative services through technological advancement.

**Figure 9: Industry Value Added** (% of GDP)




GDP = gross domestic product.
Source: World Bank Database.

**a. Pre-industrialization phase (~1975)**

**Before the independence (1955–1971)**: Prior to independence from Pakistan, three Five-year Economic Development Plans (1956–1970) were implemented. However, the economic growth in East Pakistan (currently Bangladesh) was slow due to discrimination of West Pakistan (currently Pakistan). West Pakistan established the regional branch of Pakistan Council of Scientific and Industrial Research in 1955 in Dhaka, which was the first scientific research organization in East Pakistan. However, discrimination toward East Pakistan led to slow growth in S&T. At the time of Bangladesh's independence, six research organizations had 20 institutions operating under their authority.

**After the independence (1971–1975)**:_After independence from Pakistan, Bangladesh inherited its industrial policy framework, which focused on bureaucratic control of mostly the private industrial sector with an emphasis on import substitution and nearly exclusion of FDI (Yunus & Yamagata, 2012). The first industrial policy soon after independence was announced in 1972 focused on maintaining tight control over the economy and started to nationalize all large-scale industries, particularly jute and cotton textiles, sugar, and most banks (Islam, 1985). Limits were imposed on private investment and FDI. Although the regime at the time advocated "socialism," it increased the middle class by increasing white-collar jobs and self-employed private traders by raising public spending, which was closer to "state capitalism" (Islam, 1982). These development policies led to opposition from other classes, and during the economic contraction period, problems with the middle class occurred, resulting in coups in 1975 (Islam, 1982). Bangladesh was plagued with many social issues, such as poverty and illiteracy, and faced political instability. Hence, the Bangladeshi government's S&T policies fell short of its priorities.

**Table 21: Position of State and Private Sector in Industry Before and After Nationalization**

| Ownership | 1969–1970 | | After 1972 | |
|---|---|---|---|---|
| | **Value of Asset** (Tk million) | **Share of Fixed Asset** (%) | **Value of Asset** (Tk million) | **Share of Fixed Asset** (%) |
| State | 2,097.0 | 34 | 5,637.5 | 92 |
| Private | 4,040.5 | 66 | 500.0 | 8 |

Source: Islam (1985).

**b. Industrialization phase (1975–present)**

**Gradual opening up era (1975–1990)**: In 1975, after the coup, policies dramatically changed to broaden the scope for private sector participation. Policies, such as private investment ceiling were abandoned, and generous lending by the commercial bank was implemented. As a result, giant multinational firms initiated the investment and boosted the Bangladesh economy. Daewoo and other ROK firms entered the Bangladesh market. In 1982, the New Industrial Policy (NIP) announced a considerable effect on the industry. Extensive privatization took place, and the market changed dramatically. NIP was revised in 1986 to further expand, relax, and strengthen the measures required for privatization through a deliberate privatization program.

**Macroeconomic reform era (1990–2000)**: The government of Bangladesh introduced the Industrial Policy in 1991 to promote the market economy. This policy made the government role "promotional" rather than "regulatory." Nearly all sectors [excluding some sensitive sectors (i.e., production of arms and ammunition, nuclear energy, and security printings)] were open for investment according to the policy. The policy allowed 100% FDI, as well as a joint venture with a local private sponsor and the public sector. The Privatization Board established in March 1993 under the 1991 Policy was entrusted with privatizing SOEs identified, whether small, large, and profitable or unprofitable.

From the 1980s to the 1990s, drivers of economic growth were low-technology sectors, such as garments, cosmetics, and pharmaceuticals, aimed at the domestic market and low-technology primary sector exports, such as shrimps (Khan & Blankenburg, 2009). Despite the weak technological base of these sectors, they became the foundation for further growth in high-technology sectors. The small capitalist sector grew and became drivers of a bottom–up variable of capitalism, which created a growth without external technology acquisition (Khan & Blankenburg, 2009).

**Table 22: Industrial Policies of Bangladesh**

| Year | Policy Name | Major Activities |
|---|---|---|
| 1973 | Industrial Investment Policy | • Nationalization of all medium- and large-scale industrial policies |
| 1974 | New Industrial Investment Policy | • Encouraging private sector activities in manufacturing and reducing the dominant role of the public sector though disinvestment |
| 1975 | Revised Investment Policy | • Focus on private sector-led growth; the period witnessed large-scale denationalization of industrial enterprise<br>• Private sector investment began to accelerate with liberal credit policies and generous lending by commercial banks and FDIs<br>• Boosting export sector |

| | | |
|---|---|---|
| 1982 | NIP | • Assign the private sector the pivotal role in rapid industrialization of the country<br>• Stimulate industrial development though the private sector<br>• Large-scale denationalization |
| 1986 | Revised Industrial Policy | • Consistent with the government's policy of balanced regional development |
| 1991 | Industrial Policy | • The entire industrial policy was based on the philosophy of market-based competitive economy<br>• Elimination of concessionary interest and provision of special credit facilities<br>• Removal of permission requirement to establish industries<br>• Removal of restrictive provisions for equity participation by foreigners<br>• Promotional rather than regulatory |
| 1999 | Industrial Policy | • The first policy envisioned industrial development, and the objectives outlined in the policy statement had clear sense of direction<br>• Its major objective was to create sizable industrial sector where manufacturing would account for at least 25% of GDP and 20% of employed workforce<br>• Openness to trade competition and integration with the global economy |

Source: Bangladesh Economic Review (2017).

**Deepening FDI era (2000–2010)**: In the 2000s, import liberalization deepened. Given the rising wages in the PRC, factories that needed cheap labor moved from the PRC to Bangladesh. Bangladesh's minimum wage was only US$ 95, which is less than the PRC's US$ 289 and that of other Southeast Asian countries (i.e., US$ 182 in Cambodia and US$ 180 in Hanoi and Ho Chi Minh; SCMP, 2019). According to the United Nations Conference on Trade and Development, FDI in Bangladesh surged 68% to a record high of $3.61 billion last year, which is more than triple the amount in 2011 (Nikkei, 2019). Bangladesh's GDP continued to grow, and it became a lower–middle-income economy country in 2015.

Bangladesh has been experiencing a steady increase in the growth rate of real GDP since its independence, accelerating from an average of less than 4% during 1972–1990 to 6.5% in 2010–2016. Bangladesh is one of the 16 countries that must move out of LDC and low–middle-income status (WDI 2016 database). However, low technology with cheap labor manufacturing industry cannot generate the necessary pace of income growth.

**Innovation-oriented era (2010–present)**: Bangladesh established innovation policies along with industrial policies. Representative innovation policy is the implementation of "Digital Bangladesh" declared manifesto by the ruling party through an organization called "a2i" (access to information) in 2007, a direct agency of the Prime Minister's Office. Digital Bangladesh emerged not only as a vision but also as a unique development approach to leverage ICT in delivering the social goods for the underserved. A2i is a special program of the Bangladesh government that catalyzes citizen-friendly public service innovations, simplifying the government and bringing it closer to people. A2i drives the creation of a public service innovation ecosystem and delivery infrastructure working closely with local administrations. It has empowered thousands of civil servants to redesign services in a citizen-centric manner and launch "Innovation Projects" around the country, especially at the field level.

In the 2010s, the Bangladesh government formulated the National Science, Technology, and Innovation (NST&I) Policy considering innovation-based development. The prime objective of the updated NST&I Policy is to ensure application(s) of STI for achieving sustainable economic growth with due attention to employment generation, poverty alleviation, gender equity, and environmental sustainability. To encourage research and innovation in areas relevant to economy and society, close and productive interactions must be promoted between private and public institutions in S&T and PPPs in R&D activities.

The ICT division under the Ministry of Posts, Telecommunication, & ICT introduced fellowship, scholarships, and grants to support individuals or organizations for encouraging innovative work in ICT through funding. Innovation projects that can contribute to the ICT sector for the country's socioeconomic development, public service, or creation of new innovative services can avail the funds. Personal-, educational-, institution-, or organization-based projects can contribute by using ICT in the country's education, health, agriculture, economy. Development of women can avail special grants. The ICT division has established high-technology and S/W technology parks in several areas and supported one project to establish innovation-based IT business incubator in Chittagong University of Engineering and Technology. The ICT Act 2006 (as amended in 2013) was formulated to achieve Vision 2021 for Digital Bangladesh. Several innovative projects have been executed by the ICT division, such as learning and earning development projects, mobile game and application development projects, four-tier data center projects, establishment of innovation and entrepreneurship development academy, establishment of S/W quality testing and certification center, development of national ICT infra-network for Bangladesh government (Info sorkar phase-3), and establishment of Digital Island Moheskhali.

**Table 23: Innovation Policies of Bangladesh**

| Year | Policy Name | Major Activities |
|---|---|---|
| 2008 | Vision 2021 - Digital Bangladesh | • Unique development approach to leverage ICT in delivering social goods for the underserved<br>• Quality healthcare, productive agriculture, efficient judicial process, responsive law enforcement, reduced environmental vulnerability, effective and efficient social security, hassle-free land management, and economic prosperity<br>• Fostering public service and social innovation, catalyzing fintech, empowering Bangladeshi youth with future skills, and reorganizing the work of government through shared application programming interfaces |
| 2010 | Perspective Plan 2020–2021, prepared by PC | • Ensuring per capita energy consumption increase to 600 kwh<br>• Raising per capita income to US$ 2000<br>• Strengthening information technology toward a digital Bangladesh.<br>• Innovative people will be the foundation of the envisioned society |
| 2011 | NST&I Policy 2011 | • Coordinating scientific research in research institutions and universities and that between industries and research organizations<br>• Considering innovation-based development, promoting S&T as stewardship of positive change in society and for balanced socioeconomic transformation<br>• PPPs in R&D activities<br>• Appropriate legal and policy instruments for implementation<br>• Strengthening of intellectual property right regime<br>• Promoting awareness about the importance of STI among all actors<br>• Mobilizing sufficient research and training funds, venture, and investment capitals |
| 2013 | ICT Act 2006 (as amended in 2013) | • To develop ICT-based applications to provide citizen centric services through proper security<br>• Projects that can contribute by using ICT in country's education, health, agriculture, and economy; development of women can avail special grants<br>• Establishing S/W quality testing and certification center, developing national ICT infra-network for Bangladesh government (Info sorkar phase-3), and establishing Digital Island Moheskhali |

Source: Authors' creation.

## 3. Innovation Policy Governance

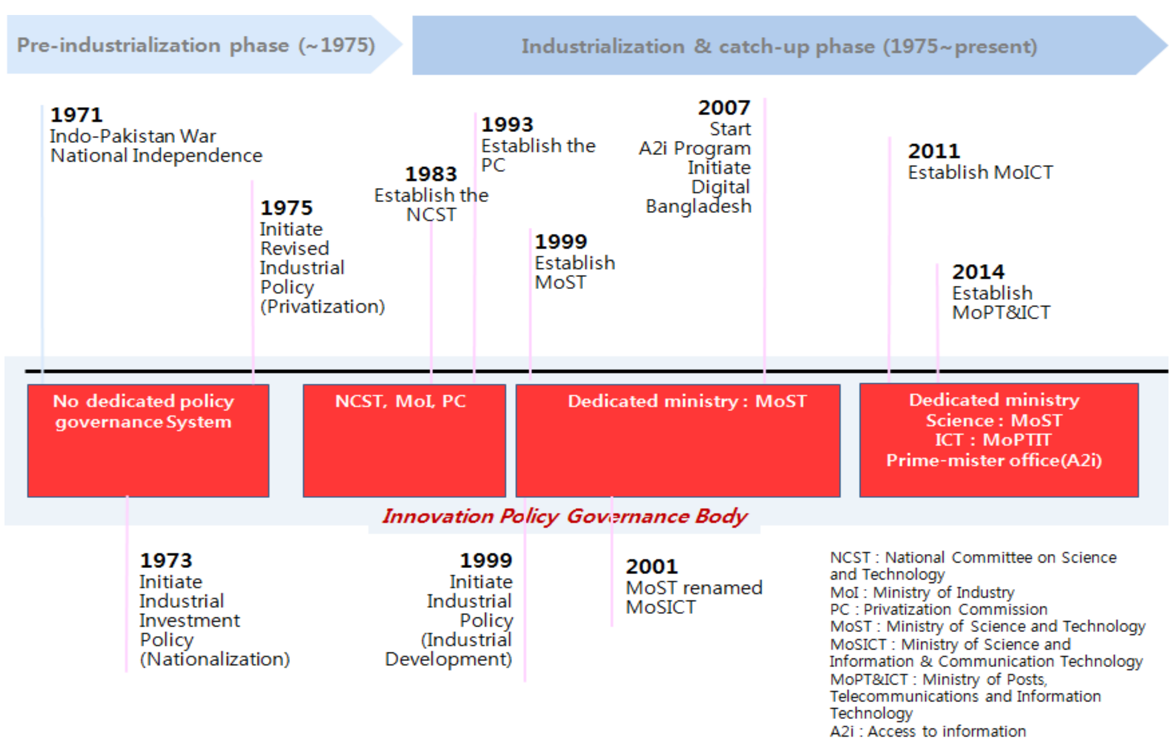
Bangladesh's innovation policy governance system underwent several changes. Immediately after the liberation, no organization was dedicated to policy. In the 1980s, industrialization and export were expanded under the industrialization policy, and privatization system was introduced in the market. Therefore, when the Privatization Commission was established in 1993, the Ministry of Industry became the key body of innovation policy governance.

Throughout the 2000s, many ministries competitively participated in S&T policies. The MoST was established, in which Bangladesh Atomic Energy Commission, Bangladesh Council for Scientific and Industrial Research, and Bangladesh Institute of Biotechnology were the major organizations.

In 2011, the Bangladesh government established and transferred ICT-related policies to the Ministry of ICT from MoST, which indicated the government's interest in fostering information and communication technologies and industries. In 2014, the Ministry of Posts, Telecommunications, and Information Technology was established because of governmental reformation. The change proved the understanding the importance of ICT from the highest policy level. A2i program under the Prime Minister's Office delivered citizen-centric services with innovations in line with the Vision 2021. Then ICT Division and Planning Ministry formulated STI-based policy to make the nation digital through technological innovation-based solutions and made a favorable environment that provided digital service to the nation.

In response to the need for strong coordination, the ruling parties formed innovation clusters through a central innovation team headed by Prime Minister, with representatives from potential offices as innovation team members. A2i, ICD, PC, and other related offices worked hard to provide favorable policies and directions to encourage innovation and tailored services to citizens through using advanced S&T.

**Figure 9: Changes in Bangladesh's STI Governance System from 1971 to Present**




Source: Authors' creation.

## III. CONCLUSIONS

### A. Three Suggestions for Enhancing the National Innovation System (NIS)

This study begins with an assumption that a well-designed innovation policy and its actual implementation will eventually lead to high economic performance. On this basis, the evolution of innovation policies of eight countries was reviewed according to three economic development phases, namely, pre-industrialization, industrialization and catch-up, and post catch-up. The results show that Japan, the ROK, and the PRC have reached the last stage (i.e., post catch-up), whereas the other five countries are stuck in industrialization and catch-up stage. Therefore we conjecture that there exist distinctive innovation policies that can divide the above two groups: a group of having reached the post-catch-up phase and another group of having not reached that stage. We try to present the specific innovation policies from the national innovation system (NIS) perspective. Why we used the NIS approach? It is because NIS perspective is recently the most widely accepted theoretical view and a comprehensive approach which can deal with everything such as actors, interactions, administrative role, and institutions involved in innovation at the national level. In conclusion, we found out that there exist the innovation policies which Japan, the ROK, and the PRC commonly used, but Malaysia, Thailand, Indonesia, India, and Bangladesh considered less critical. And the innovation policies significantly help (1) to strengthen actors' innovation capability and increase their interactions, (2) to advance the government's role, and (3) to make a better institution and then eventually to be a strong NIS. Our three suggestions and specific actions for enhancing the NIS through the review of eight Asian countries are summarized as follows.

#### 1. Enhance actors' Innovation Capability and Increasing Their Interactions

One of the significant elements consisting of NIS is actors, such as firms, universities, public research institutions. Actors must be armed by strong technological capability because they are the primary sources of creating innovation, and they should also be closely interactive for generating synergetic effects among them. For doing this, we need the following four measures: (1) political stability and industrialization should be first settled; (2) acquisition, diffusion, and internalization of advanced technologies need to be facilitated; (3) interactions among actors have to be promoted; and (4) innovation input such as R&D expenditure and R&D human resources should be enough.

##### a. Securing political stability and being successful industrialization

The majority of the eight countries experienced industrialization after the Second World War or after the acquisition of national independence. Political instability substantially slowed the speed of industrialization. The adverse effect of unstable political situation was observed in Indonesia, Thailand, and Bangladesh. Japan, the ROK, and the PRC were successful in industrialization through relatively quick recovery of political stability after the Second World War or Civil War, in which the GDP portion of the secondary industry surpassed that of the primary industry, which accelerated the catch-up process. Thus, political stability and industrialization are prerequisites for successful catch up, which is a result of high innovation performance.

##### b. Facilitating acquisition, diffusion, and internalization of advanced technologies

Japan, the ROK, and the PRC facilitated the acquisition of advanced technologies from overseas, diffusing them to private sectors and encouraging indigenous firms to internalize them in a government-led manner. Particularly, Japan and the ROK used foreign debts rather than FDI for importing oversea technologies, securing their technology independence from multinational firms. By contrast, the PRC actively used FDI for foreign technology acquisition with the condition that FDI was allowed by establishing a joint venture with indigenous firms, resulting in the efficient transfer of multination firms' technology to Chinese firms. In conclusion, which is better among FDI, JV, and foreign debts is unimportant. What matters is how much actively developing countries request MNCs to transfer their technology to developing ones.

Regarding technology diffusion and internalization, all three countries preferred the same method, which emphasized the role of PRIs as developers and technology transferors between the government and firms. Particularly, the Government of the ROK gave R&D subsidy to PRIs, and in return, PRIs developed industrial technologies and transferred them to the ROK's *chaebols* for commercialization. Later, *chaebols* invested money with the government into the large-scale national R&D projects and performed R&D activities with PRIs and developed technologies. Also, Japan, the ROK, and the PRC often protected local firms from multinational firms for the technology internalization of indigenous firms. In India, Indonesia, Thailand, and Malaysia, PRIs' capabilities of technology development seem useful; however, their capacities of diffusing the technology to the private sector appear lacking. These countries' firms also have weak abilities to internalize advanced technologies. Therefore, for successful catch-up, a cycle of acquirement, diffusion, and internalization of advanced technology is needed to be smoothly circulated.

#### c. Encouraging cooperation among institutions-industry-university

For efficient spin of the cycle of acquirement-diffusion-internalization of advanced technology, strong interactions and collaborations among the public, industry, and universities are the most useful. It is because each among the three parties has different resources and conditions. PRIs can focus on basic research thanks to enough resources and less pressure on making profits than firms. On the other hand, industries are mostly compelled to do applied research because of the enormous pressure of quick commercialization for generating profit. The university does not have any pressure on generating profits but has not enough facilities and equipment to do a grand R&D project compared to those of PRIs. Therefore, only if these three parties cooperate they can continuously improve their technology and enhance indigenous firms' technological capabilities by using a synergy effect occurred between basic research and applied research, and among PRIs, universities, and industries. Japan, the ROK, and the PRC had many experiences of successful cooperation among these three parties.

#### d. Increasing innovation input, R&D expenditure, and R&D human resources

The tables of innovation performance indicate that Japan, the ROK, and the PRC had higher investment in R&D expenditure, researchers, and technicians compared with the other five countries. Given their high level of innovation inputs, all three countries achieved considerably higher innovation outputs than other countries. Regarding the R&D expenditures, the ROK was the highest with 4.5% of GDP in 2016, followed by Japan and the PRC with 3.1% and 2.1% of GDP in the same year, respectively. By contrast, the remaining of five countries, except for Malaysia, had R&D expenditure of less than 1% of GDP. Malaysia's R&D expenditure barely surpassed 1% of GDP (1.3% of GDP in 2015). Furthermore, Indonesia, Malaysia, and Thailand have always been suffering from a lack of R&D human resources, which is a natural cause and effect, that is, less input brings low outcomes. Therefore, to increase the level of innovation outcomes, investment should be made in innovation inputs, such as increasing R&D expenditure, fostering researchers and technicians, and establishing research institutions.

### 2. Advance Government's Role

The government is one of the primary actors of NIS, but we separately try to describe from the other actors because the government is the subject of planning innovation policy. The role of government in the process of formulating innovation policies is overwhelmingly important. The government should be able to change its role according to the economic development stage. In other words, it is necessary to act as a provider and regulator in the early economic development stage. However, after a catch-up phase, it should act as a coordinator to foster an environment where private sectors can create innovation by themselves. Besides, the government needs to develop insights on seizing and realizing the opportunity when the window of opportunity opens. It also can establish a concentration and selection strategy, and detour strategy based on accurate identification of the national resources and competences.

### a. Evolving governmental role from provider and regulator to coordinator and facilitator

For the success of industrialization and catch-up, Japan and the ROK used a government-driven policy. Although the PRC used the same strategy, the PRC was excluded from this issue because its political system is relatively different from that of other countries as a one-party rule. The governments of Japan and the ROK initially invested huge capitals into establishing universities, especially enhancing the engineering and science departments of universities, building PRIs, and fostering and distributing S&T talents. They also planned national R&D projects and enforced indigenous firms, PRIs, and universities to participate in these projects through financial aids and various incentives to strengthen domestic technological capabilities. They also established various science parks or industrial clusters for building an innovation eco-system and formed various regulations that boost the R&D activities of indigenous firms.

At the beginning of industrialization and catch-up, both governments provided and regulated everything for increasing national innovation capabilities. However, after setting up their NIS and accumulating indigenous firms' technological capabilities, they changed the roles from providers and regulators to coordinators and facilitators. They handed over to the private sector the functions of supporting and regulating R&D activities. Both governments' roles evolved according to the national innovation capability level. The most apparent evidence of this evolution was the radical decrease in public R&D expenditures. For instance, the ROK's private R&D expenditure began to surpass its public R&D expenditure since the 1980s. In 2017, the ROK's ratio of private and public R&D expenditure was 78:22. For Japan, before the 1970s, Japan's indigenous technology improvements had already begun to be led by the private sector. Japan's ratio of private and public R&D expenditure was 79:20 in 2017, and even the PRC's rate of private and public R&D expenditure approximated those of both countries (76:20 in 2016).

India, Indonesia, and Malaysia had a higher ratio of public R&D expenditure than private R&D expenditure. Although these countries achieved success in industrialization and great success in a particular industry, they have not reached the successful catch-up phase because their indigenous firms still heavily rely on government supports rather than building technological capabilities by themselves through active R&D. Therefore, for the future, their governments should strengthen the role of facilitating their domestic firms to increase R&D expenditure rather than the task of providing everything.

### b. Optimizing windows of opportunity

The concept of window of opportunity refers to the idea presented by Perez and Soete (1988), who observed that a new techno-economic paradigm (e.g., emergence of digital technology and trade liberalization) could be an excellent opportunity for latecomers to enter new sectors. The windows of opportunity also arise in change in business cycle (i.e., downturn or upturn) and change in regulation or government intervention (e.g., deregulation). Successful catch-up cases effectively leverage windows of opportunity. We can find those cases in India's IT services (change in IT service business model and change in government policy on foreign firms' liberalization), the ROK's digital TV and mobile handsets (emergence of digital technology), and the PRC online game industries (government's interference on foreign firms do not allow foreign firms to be publisher). Therefore, ASEAN countries should anticipate what the windows of opportunity will be and determine the most effective method.

### c. Using the selection & concentration strategy for efficient leverage of limited resources

All countries have limits in their resources and differ in their competent fields. Developing countries are lacking in all aspects of finance, technology, people, and infrastructure. Therefore, the strategy of selection and concentration is useful to latecomers for efficiently allocating resources and quickly achieving goals. Japan, the ROK, and the PRC all selected highly competent fields, established long-term innovation plans for developing the selected sectors, and implemented policies step by step during industrialization and catch-up stage, and even after. For example, Japan focused on steel, automobiles, and shipbuilding during the industrialization stage; on mechanical and chemical, electronic, and automotive during the catch-up stage; and on biotechnology, fine

chemistry, and robots during the post catch-up phase. The ROK also focused on the light industry in the early stage of industrialization and moved to heavy industry, shipbuilding, steel, IT hardware, automobiles, and semiconductors. In the 1980s, the PRC also invested in seven high-technology sectors (i.e., biotechnology, aviation, IT, laser, automation, energy, and new materials) through the 863 Plan. All three countries have been using this policy under the name of "national strategic industries."

India has failed to set priorities in areas having high competitiveness and has no long-term innovation roadmap for improving the fields with high priority. It recently established a long-term innovation policy of enhancing the pharmaceutical, IT service, and car component industries and presented high innovation performance in these industries. Therefore, for fast catch-up and efficient resource leverage, it should consider a selection and concentration strategy. For implementing reasonable selection and concentration on a specific field, a long-, mid-, or short-term innovation road map should be based on the analysis of industry/technology forecasts, marketability, and national competitiveness.

**d. Using detour strategy of specializing in short-cycle technologies**

According to Lee (2019), the cycle time of technologies is a determinant of the late entry and speed of technological catch up. The technology of long life expectancy makes developing countries invest considerably more resources for mastering it for catch up than the technology of short life expectancy does. Therefore, developing countries with severe resource constraints can achieve substantial advantages by targeting and specializing in sectors associated with short-cycle technology. The sectors have characteristics of disruption of incumbents' dominance often occurring; however, the continuous emergence of new technologies generates new opportunities. This detour allows developing countries to avoid direct competition with global leaders. The ROK has most successfully implemented this detour strategy. It began to specialize in labor-intensive (low value-added) industries, such as apparel or shoes, in the 1960s. It moved to shorter- or medium-cycle sectors of low-end consumer electronics and automobile assembly in the 1970s and 1980s; shorter-cycle telecommunication equipment sector in the late 1980s; and memory chips, cellphones, and digital televisions in the 1990s.

India did not use this detour strategy but invested many resources in long-cycle technologies, such as defense, space, and nuclear program from the early stage of industrialization, which may be an important reason for India's slow catch-up speed. Indonesia made a similar mistake. Since the late 1970s, Indonesia's government has driven a project specializing in long-cycle technology, such as the aircraft industry. However, the project failed, generated massive financial costs, and triggered huge layoffs. Therefore, ASEAN countries must consider the detour strategy of specializing in short-cycle technologies, especially during the early stage of industrialization and catch up.

### 3. Make a Better Institution

It is essential to make excellent innovation policies, but it is also essential to coordinate the policies created by many ministries and public agencies with consistency. Innovation policy also needs to be able to execute effectively and to reflect the latest policy trends. All of these are included in the institutions; thus, we should try to make a better institution. In conclusion, it is needed to (1) establish a powerful coordination governance body, (2) strengthen the enforcement of laws, and (3) reflect innovation policy trends to solve social problems.

**a. Building innovation policy governance body that strongly coordinates across ministries**

All eight countries, including Japan, the ROK, and the PRC, confronted the difficulties in coordinating numerous innovation policies spread over all ministries and public agencies. At the beginning stage of recognizing the importance of S&T for economic development, S&T policies were few, and managing and implementing S&T strategies were relatively easy. Given the few ministries and agencies requiring S&T plans, the function of coordination was simple and less demanding. However, as industrialization and catch-up activities progressed, the necessity of innovation policy spread over all ministries and agencies. In countries with

highly independent local governments, such as Japan, the PRC, Indonesia, and India, the mismatches of innovation policy between central and local governments emerged as substantial issues. Therefore, a higher-level coordination body must gather all needs of ministries, agencies, local governments, and central governments and adjust priorities and budgets. Moreover, this body must use an approach that combines top–down and bottom–up approaches rather than an approach that emphasizes a top–down approach for conducting demand-oriented R&D investments. For the smooth implementation of the higher-level organization, a strongly dedicated ministry, as a secretariat, is required for collecting and communicating all information and opinions related to innovation policy between coordination bodies and ministries, agencies, and local governments.

The ROK gave broad roles (i.e., planning, reviewing, adjusting, budgeting) and massive power to the MoST and OSTI by upgrading the minister of the MoST to deputy prime minister. It also strengthened the position of the NSTC, the higher-level coordination body, by designating the president at its chairman. Its innovation policy governance system worked well with strong coordination and consistency. Japan also had the MITI (later changed to Ministry of Economy, Trade, and Industry) as a dedicated ministry. The MITI placed a considerable power to the high-level coordination body, namely, Council for S&T (later changed to Council for S&T policy and then to Council for STI), by locating the organization under the Cabinet Office.

Malaysia has been suffering from a difficulty of planning and implementing innovation policies with consistency because of its numerous ministries, public agencies, and institutions that are involved in the NIS. Indonesia and Thailand also have the same problem. Therefore, they need a reliable and single dedicated ministry and a high-level coordination organization to actively harmonize all innovation policies with an approach of combining top–down and bottom–up approaches.

#### b. Establishing legal framework for high implementation of innovation policies

Japan and the ROK enacted a national law called the Act on S&T in 1995 and 2001, respectively. On this basis, both countries established the Five-year STBP for resolving new challenges that emerged from the post catch-up phase, providing an overarching guide for the conduct of STI policies and improving the execution power of policies. The ROK observed the great success of the Japanese S&T legal framework, which was adopted under the same name of law and plan. With the Act and the Plan, the ROK achieved high implementation of innovation policies with consistency as planned. By contrast, India regarded S&T as one of the essential tools for economic development considerably earlier than the other countries and announced substantial S&T policy statements at least four times. However, it could not execute innovation policies as planned because it heavily relied on policy statement rather than a legal framework, which resulted in no legally binding policy. Therefore, a legal framework should be considered to increase the implementation power of innovation policies.

#### c. Using innovation policies to solve social problems in addition to improving economic growth

Recently, Japan has been using innovation policies to address social “issues,” such as aging, disasters, and environmental problems. To change the various challenges of Japan into a growth engine with a goal of 2020, Japan has been transforming itself into a “leading country in solving the social challenges.” The ROK is taking similar measures. For instance, the innovation policy presented by the “Korean Vision 2040 of STBP” includes issues for improved human society and economic and scientific development issues. Innovation policies previously aimed at economic growth now seek to improve the quality of life and solve social problems, such as diseases, environment, climate change, unemployment, and lack of resources. Given that social demands drive this change, that trend will soon spread worldwide. Therefore, ASEAN countries who have not prepared for responding to social needs must understand their every society’s needs and apply them to their innovation policies.

### B. Common Innovation Policy Instruments by Economic Development Phase

On the basis of the expectation that the policy instruments can be changed in each stage of economic development, the evolution of policy measures in Japan, the ROK, and the PRC, who have gone through three phases of economic development, were investigated (Table 24). If a common policy tool is used in each stage, then it can be a guideline to ASEAN countries placed at a specific economic stage. We found standard innovation policy instruments at each economic development stage through a review of eight Asian countries as follows.

**Pre-industrialization phase**: At this stage, necessary infrastructures in all aspects of economy, politics, S&T, and education, were markedly weak due to the Second World War or civil wars. Therefore, the critical policy instrument during this stage is building various foundations that help S&T growth under government leadership. These measures include the establishment of educational institutions to reduce illiteracy rates, the foundation of PRIs, the promotion of S&T talents, and the construction of a Social overhead Capital (e.g., railroads, ports, and roads). Import substitution policy (the ROK), government-led technology import policy (Japan), and five-year plan and 10-year S&T plan (the PRC) were not standard policy tools. Nevertheless, they were suitable for the context of each country.

**Industrialization and catch-up phase**: The two most important goals during this phase are the success of industrialization and the accumulation of indigenous firms' technological competence. For successful industrialization, three countries used the selection and concentration strategy, which selected and invested in specific sectors, and the five-year economic plan. Direct R&D grants, R&D tax credits, programs of training and skills, formation of cluster or technological parks, and unfriendly regulations for foreign firms were also utilized to improve local firms' technological competitiveness. These instruments were thoroughly government-led, pursuing innovation that focused on supply-dominated R&D investment and short-term technology development.

**Post catch-up phase**: The countries at this stage are no longer followers but leaders. Thus, as innovation leaders, they must upgrade industrial and social structures in addition to institutional and legal systems. Private sectors should generate innovation by themselves rather than relying on the government's direct aids, and innovation should spread to SMEs, start-ups, and large corporations. Thus, primary policy instruments during this phase include the enactment of law, such as STBP, enhancement of IPR system, private-led innovation, long-term technology development, social issue-solving-oriented innovation, demand-dominated R&D investment, encouraging start-ups (entrepreneurship), promotion of open innovation with global R&D partners, and public procurement for promoting SMEs' innovation.

**Table 24: Major Innovation Policy Instruments Used by Economic Development Phase**

| Name of Country | Major Innovation Policy Instruments Used by Economic Development Phase | | |
|---|---|---|---|
| | Pre-industrialization | Industrialization and Catch-Up | Post Catch-Up |
| Japan | [1868–1888]<br>• Preferential treatment to foreign engineers<br>• Government-sponsored import policies started the acquisition of light industry technologies, such as textiles. | [1889–1979]<br>• Promoting foreign equipment imports<br>• Government-led technology policy in selected sectors (i.e., heavy industry, automotive industry, and shipbuilding)<br>• Government-supported institutions<br>• Technology transfer programs and S&T education<br>• Indigenous technology improvement led by private companies investing in R&D<br>• For the development of in-house indigenous technologies, government focused on the long term, high-cost and high-risk investment research | [1980–present]<br>• Private investment in new equipment and machinery has soared<br>• Focus more on complex and sophisticated technologies while investing more on basic research<br>• Enact the S&T basic law and implemented 1st to 5th STBP (1996–2021)<br>• Leverage innovation policies to address social issues.<br>• Increase policy predictabilities for private companies by providing mid- and long-term policy milestones based on the governance system combining bottom–up and top–down decision-making approaches |
| Republic of Korea | [1945–1959]<br>• Build basic infrastructures (e.g. roads, railways, telecommunications, ports etc.)<br>• Fight illiteracy<br>• Import substitution policy | [1960–1999]<br>• Use the national plan, namely, the Five-year Economic Development Plan<br>• Government-led innovation policy in selected sectors (i.e. apparel and shoe in the 1960s; consumer electronics and automobile assembly in the 1970s and 1980s; and memory chips, handsets, and digital TV in the 1990s)<br>• Import advanced technology through foreign debts rather than FDI<br>• Direct support to *chaebols*' R&D and innovation<br>• Government research grants for universities, GRIs, firms through national R&D programs<br>• Build science park or innovation cluster, Daeduk Science Park<br>• Tax incentives for R&D | [2000–present]<br>• Use the national plan and law, the five-year STBP and the Framework Act on S&T<br>• Private and industry-led policy<br>• Targeting SMEs and start-ups (entrepreneurship policy)<br>• Policies to support collaboration or cooperation<br>• Build global network R&D system<br>• A long-term technology development strategy<br>• Build an S&T-led NIS<br>• Policies improving the quality of life and solving social problems such as disease, environment, unemployment, climate change, and lack of resources<br>• Demand-dominated R&D investment<br>• Public procurement policy<br>• Enhanced IPR system |

| Name of Country | Major Innovation Policy Instruments Used by Economic Development Phase | | |
|---|---|---|---|
| | Pre-industrialization | Industrialization and Catch-Up | Post Catch-Up |
| | | • Increase R&D human capital by establishing many GRIs, promoting university centers, and promoting private firms' research institutes<br>• Policies for training and skills<br>• Supply-dominated R&D investment<br>• Short-term technology development strategy<br>• Strengthening patent support system | |
| People's Republic of China | [1949–1977]<br>• Established CAS (China Academy of Science) in 1949<br>• Launched the first five-year plan (1953–1957) and established the Science Planning Committee in 1956<br>• The 12-year transitional Development plan (1956–1967) and the 10-year Science and Technology Plan (1963–1972)<br>• Great Leap Forward Movement (1958–60) and Cultural Revolution (1966–1976) | [1978–2010]<br>• Gradual transition strategy from socialist planned system to market economic system, from government led innovation (PRIs, state-owned enterprise) to market-led innovation (private enterprise).<br>• Build special economic zones (i.e., Shenzhen, Zhuhai, Santou, and Xiamen) and attract advanced technology through market opening and FDI.<br>• Tax incentives for FDI<br>• Foster independent innovative capability.<br>• Indigenous technological capability improvement led by private R&D investment rather than public R&D investment.<br>• Export Strategy shift from OEM to ODM to OBM<br>• Plan to cultivate 1,000 talented people for the S&T development in 2008 | [2011–present]<br>• From the "exchange market to technology" strategy to the "indigenous innovation" and "private creativity" strategy.<br>• Long-term technology development policy for industrial convergence-led innovation (China Manufacturing 2025, Internet Plus, and Next-Generation AI Development Plan)<br>• Target start-ups (Entrepreneurship policy)<br>• Public procurement policy for core technology innovation (new energy vehicles, high-speed rail)<br>• Open innovation with advanced countries (AI laboratories in the US)<br>• Enhance IPR system<br>• Western development |

Source: Authors' creation.

**C. Discussion: The Opportunity of Fourth Industrial Revolution in ASEAN countries**

The Fourth Industrial Revolution is not much different from the third one because it is based on digital technology. However, it is different from the Third Industrial Revolution in that development speed, influence width, and convergence degree of digital technology beyond expectations. It can be called a new revolution because digital technology massively affects society, economy, politics, culture, and daily life at an unprecedented rate and generates tremendous new industries. This new revolution brings an opportunity, which reforms high-growth economies to many developed countries facing difficulties of low economic growth rate. It also enables the US, Germany, and Japan, which are powerhouses of the manufacturing industry, to regain past glory. To take this opportunity, US, Germany, Japan, Singapore, and the ROK are establishing and implementing innovation policies associated with the Fourth Industrial Revolution.

However, their efforts can be a considerable threat to ASEAN countries that are not ready for such a revolution. If a fully automated production system builds through utilizing digital technologies (e.g., IoT, AI, big data analysis, cloud computing, and 3D printing), then production activities need not be left to the emerging economies. Factories of global firms can be taken from emerging countries and move onshore. The global economy today is primarily run by the Global Value Chain (GVC), which are advanced economies responsible for high value-added, upstream (i.e., design and R&D), and downstream (i.e., marketing and sales) activities. By contrast, emerging economies, such as India, Viet Nam, Indonesia, Malaysia, and Thailand, are taking the low value-added and midstream activities (i.e., manufacturing and assembly). The realization of the full-production automation system destroys the advantage of low labor costs of emerging economies. Advanced companies seek to increase their power and competitiveness in the GVC and eventually push existing participants out the GVC by incorporating digital technology.

According to the saying that threat accompanies opportunity, this revolution may bring the following opportunities to ASEAN countries that are prepared for the revolution.

First, the revolution can secure manufacturing competitiveness through active use of digital technology and strengthen ASEAN countries' position on the GVC rather than threaten their existence in the GVC. The PRC, for example, was once a great production base for multinational firms and was often referred to as the world's factory. However, its rising wages forced most global firms to move to Southeast Asian and Eastern European countries. To capitalize on this threat, the PRC is upgrading its competitiveness in GVC by strengthening cooperation with Germany, the US, and Israel, which are leading the high-technology manufacturing fields. Following the PRC's example, partnerships with global leading firms in manufacturing can be an option to maintain a strong position in the GVC.

Second, the revolution can improve domestic productivity and secure new growth foundations through the adoption of digitalization. The introduction of digital technology can increase cost competitiveness by increasing production speed, reducing defective rate, and efficiently managing logistics. Digital technology also offers many opportunities to create new businesses with small capital. Hence, economic growth can be sought through creating digital technology-based startups.

Third, the revolution can be a springboard for economic and social leap. For instance, in Africa, mobile phones proliferated without proper diffusion of fixed-line telephones. Digital technologies can provide economic and social benefits by creating new business models that can be implemented in developing countries without an accumulation of old technologies. In Southeast Asia, vehicle-sharing services such as Grab and Gojek, were popularized to overcome the lack of public transportation. In India, OYO, a lodging service provider, has been successful in solving poor accommodation services. Likewise, digital technology provides opportunities not only to create new businesses but also improve the welfare of society.

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