1.5.1 Developing economies, and science, technology, and innovation policy

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Abstract

The presence of developing economies, such as China, India, and African countries, are increasing in the global economy. This is also the same in the sphere of science, technology, and innovation (STI). This article aims to give a broad overview of the historical background of developing economies, paying attention to STI. In addition to the historical context leading up to present, the debate on building technological capability will be discussed.

Keywords

Developing economies, emerging economies, technological capability, innovation systems

1 Developing economies, and science, technology, and innovation policy

Today, there is a strong sense of awareness that science, technology, and innovation policies[1] play important role in determining the developmental pathways among developing countries. The policy attention to STI had not been so strong in the developing countries in the past.

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[1] Until recent years, science, technology, and innovation policy in developing economies was centered on "science and technology" policies for higher education and research institutions. Innovation policies have become more common in Asian and Latin American countries since the 2000s, and in African countries since the 2010s.

There are two major reasons for this. First, the policy domains covered by science, technology, and innovation policy have expanded over the years (Fig. 1). Second, the positions of developing economies are changing globally.

1.1 Science, technology, and innovation policy and social challenges

Science, technology, and innovation had previously been considered as narrow policy domain composed of tertial education and scientific research (Fig. 1, light green). As developing economies faced pressing social challenges such as poverty, lack of access to basic needs such as primary education, healthcare, and decent employment, the issue closely related to STI policy was not considered as the top priority issue in many developing countries. However, this gradually changed since around the 2010s. Many developing countries have become increasingly aware that scientific knowledge, engineering capacity (technology) and application of these in local context (innovation) are useful to address urgent social challenges. The social challenges such as climate change, infectious disease control, and digitalization required application of engineering capacity backed by the scientific evidence. It became evident that country's ability to respond to social challenges requires STI capabilities and the level of capabilities may determine the trajectory and speed of future development. Hence, STI and the policy to support development of capability are gradually considered important in many developing economies, today.

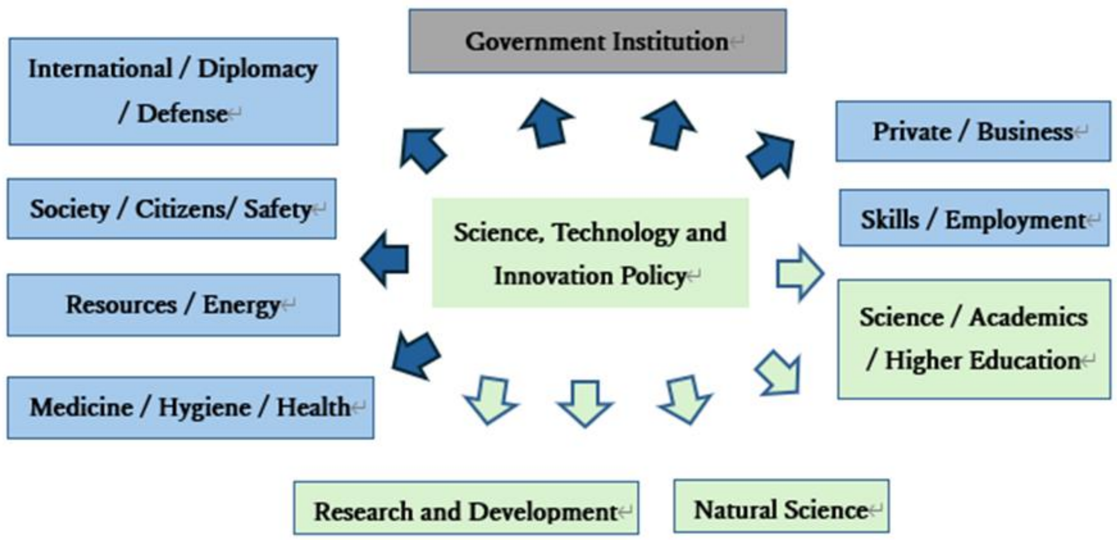
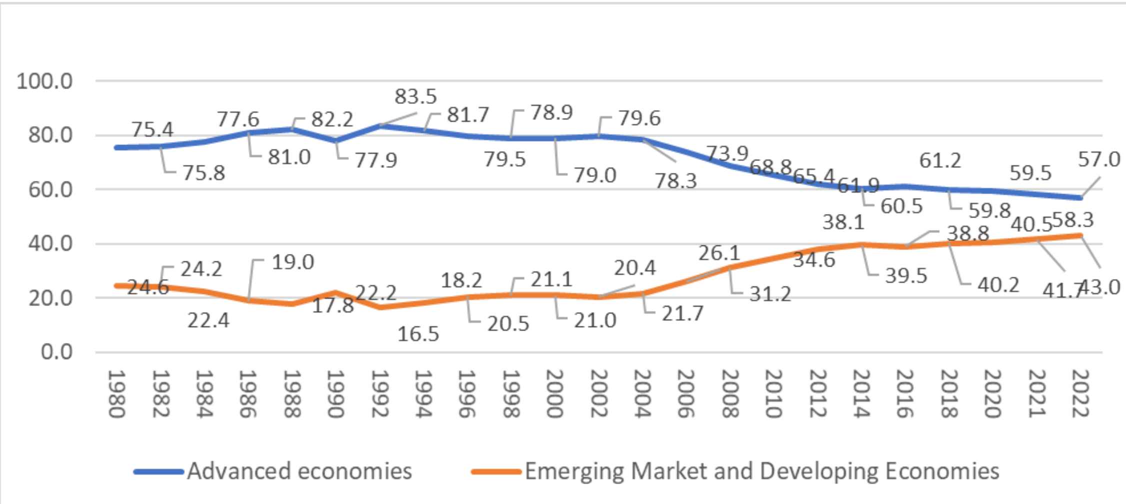


Figure 1. Related fields of science, technology, and innovation policy at the national level (conceptual diagram)

1.2 Situation of science, technology, and innovation in the developing countries in the global context

Since around the 2000s, developing economies have started to have increasing presence in global economic activities. In fact, developing economies began to increase their share of the global gross domestic product (GDP) from the 1990s (see Fig. 2). Fig. 2 compares the share of GDP of countries by advanced economies with that of developing and emerging market economies from 1980 to 2022 (IMF, 2022). The figure illustrates the widening disparity between the two groups from 1980 to 1992, moving from 75.4% vs. 24.6% to 83.5% vs. 16.5%. However, it then narrowed down since 2004 (79.6% vs. 20.4%), 2014 (61.9% vs. 38.1%) and even further in 2022 (57.0% vs. 43%). During this period, globalization of economy took place and many developing economies were integrated into global productive activities either as markets and/or production sites. Some countries leveraged the presence of foreign direct investment as well as export market to upgrade domestic technological capabilities as exemplified in the cases of East Asian countries, namely South Korea, Taiwan, Singapore and China. These countries, now a days, play critical part in manufacturing activities for companies in advanced countries.



Source: IMF data

Figure 2. Share of GDP in developing and advanced economies

Above increase in the presence of developing economies can also be seen in the political sphere. For example, the Group of Seven (G7) advanced economies[2], the main forum for discussing global issues since 1976, had been complemented with the framework of the G20, which includes the G7 countries as well as the European Union (EU) in addition to Russia, Australia and South Korea, and there are 9 rapidly

[2] United States, Japan, Germany, France, Italy, the United Kingdom, and Canada.

developing emerging economies, China, India, Brazil, Mexico, South Africa, Indonesia, Saudi Arabia, Turkey, Argentina since 1999. In other words, the emerging countries collectively participate in shaping the consensus on the global agenda concerning both economic and political spheres.

1.3 Presence of developing economies in science, technology, and innovation: terminology and indicators

(1) What is "developing countries"?

Attention needs to be given here to the changes in countries included under the "developing countries" category. During the Cold War period following World War II, "developing countries" were also referred to as the "Third World" countries, and they were treated as a homogeneous group of countries that comparable to "First World", the advanced Western countries, and the "Second World", the socialist and satellite countries that were within the sphere of influence of the Soviet Union. However, the modern understanding of "developing countries" has grown to become a much more diverse group of countries. In the Asian region, Japan, South Korea, Taiwan, and Singapore have successfully become advanced economies with manured manufacturing and service sectors, accompanied with advanced technological capability. Additionally, several countries have become emerging economies by successfully leveraging the large market size and population dividend and effectively implementing policies on promotion of foreign direct investment and export to stimulate technological transfer and capacity building. Emerging economies, such as BRICS (Brazil, Russia, India, China, and South Africa) since the 2000s and MINT (Mexico, India, Nigeria, and Turkey) in recent years, have achieved considerable economic growth and are rapidly gaining political influence. Additionally, although some low-income countries are transitioning to middle-income countries, others remain in a fragile state due to political conflicts. Moreover, countries belonging to the "developing country" category have developed at different rates, widening the gap among the countries. Fig. 2 shows the importance of emerging economies as a share of economic activity and how the presence of some emerging economies such as China and India, which belong to the G20, has increased. Next sections will discuss some of the main indicators of STI policy.

(2) Investment in research and development (R&D)

In general, it is critical for developing economies to achieve their own absorptive capacity to catch up with advanced countries. Previous research has indicated that absorptive capacity is greatly determined by the level of previous R&D investment (Cohen and Levinthal, 1989, 1990). Based on this perspective[3], an overview of R&D expenditures may indicate the level of catch-up efforts and the potential for future economic growth. Table 1 compares the share of R&D expenditures by the income level of countries between 2007 and 2018.

[3]As is discussed later, innovation or new combinations of knowledge can occur even without R&D investment.

Several insights can be obtained from looking at the trend of R&D expenditure in the share at global level.

First, the share of R&D in GDP (GERD) changed over the years across income groups. In high-income countries, the share of R&D has been decreasing over the past decade relative to the increase in the share of upper-middle-income countries. In other words, R&D is not only being conducted in high-income countries, but it is also being more actively pursued in several upper-middle-income countries. However, there are varying degrees of increase even among the upper-middle-income countries. For example, much of the increase in the share of R&D in upper-middle-income countries is caused by China, which stands out even from countries within BRICS. India has a similarly prominent presence among lower-middle-income countries.

Second, the share of R&D expenditures by low-income countries increased only slightly until around 2013, after which it began to decrease. In other words, the gap between low-income countries and the rest of economies is widening.

Table 1. Share of R&D expenditures by income level (2007–2018)

	2007	2009	2011	2013	2014	2018
High-income countries	79.70	75.60	72.60	69.30	68.20	64.36
Upper-middle-income countries	16.10	19.90	22.70	25.80	27.50	31.21
Lower-middle-income countries	4.10	4.30	4.50	4.60	4.20	4.33
Low-income countries	0.20	0.20	0.20	0.30	0.10	0.10
BRICS countries*						
China (upper-middle-income country)	10.20	13.80	16.50	19.60	21.18	24.84
India (lower-middle-income country)	2.70	3.00	3.20	n.d.	2.94	3.06
Russia (upper-middle-income country)	2.00	2.00	1.70	1.70	1.62	1.28
Brazil (upper-middle-income country)	2.10	2.10	2.30	2.20	2.40	1.88
South Africa (upper-middle income country)	0.40	0.40	0.30	0.30	0.31	0.29

Source: UNESCO, 2021

Note: *India is the only BRICS country ranked as a lower-middle-income country (2018). n.d.-No data available.

(3) Innovation (GII)

Innovation can occur even without R&D expenditures (Huang et al., 2010), and this trend is noticeable in developing economies. As innovation can boost productivity and contribute to economic growth, innovation also needs to be examined apart from the R&D expenditure. In this section, I provide an overview of innovation performance among low- and middle-income countries. WIPO calculates the level of innovation for the level of development at the country level. The chart below is composed of GDP per capita on the horizontal axes and GII score on the vertical axis. The low- and middle-income countries which are performing better in innovation performance, measured by WIPO's GI index, than the expected level by the income category are demonstrated in the figure.

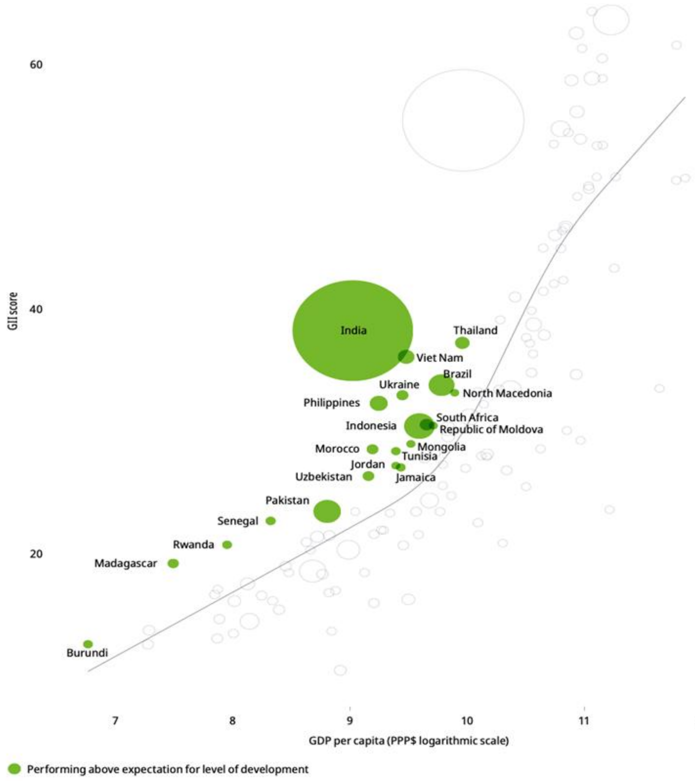


Figure 3. Low- and middle-income countries implementing innovation above their income level.

Source: Global Innovation Index Database, WIPO, 2023. Note: The size of the circle is the size of the population. The line indicates the level of innovation performance indicated by GII2023, which is assumed to be the level of GDP per capita. GII score refers to a composite indicator of innovation.

The WIPO Global Innovation Index (GII) indicates each country's innovation activities using a composite index to facilitate international comparison. The above graph is published every year by WIPO. Fig. 3 shows data only for 2023; Table 2 supplements that data with time-series information from 2011 onward. Table 2 demonstrates that only few countries consecutively performed better in innovation in the period 2011-2023. These countries are: India, Moldova, Vietnam, Mongolia, Rwanda, Ukraine, and Thailand. Further, these countries are not concentrated in the upper-middle-income group but rather exist at all income levels, including the lower-middle and low-income groups. In other words, innovation performance is not determined by the income level; instead, other factors may influence: including types of policy, industrial activities, and human resources, ultimately contributing to the development of the country. Essentially, discerning future trends in developing economies requires paying attention to the current situation of science, technology, and innovations in developing and emerging economies at various income levels.

Table 2. Low- and middle-income countries with innovation performance that exceeded expectations. (2011-23)

Country	**Income level**	**Year with results that exceeded expectations**
India	Lower-middle income country	2011–2023 (13 years)
Moldova	Upper-middle income country	2011–2023 (13 years)
Vietnam	Lower-middle income country	2011–2023 (13 years)
Mongolia	Lower-middle income country	2011–2015, 2018–2023 (11 years)
Rwanda	Low-income country	2012, 2014–2023 (11 years)
Ukraine	Lower-middle income country	2012, 2014–2023 (11 years)
Thailand	Upper-middle income country	2011, 2014–2015, 2023 (11 years)
Jordan	Upper-middle income country	2011–2015, 2022–2023 (7 years)
Madagascar	Low-income country	2016–2018, 2020–2023 (7 years)
Senegal	Lower-middle income country	2011–2015, 2017, 2023 (7 years)
South Africa	Upper-middle income country	2018–2023 (6 years)
Morocco	Lower-middle income country	2015, 2020–2023 (5 years)
Philippines	Lower-middle income country	2019, 2020–2023 (5 years)
Tunisia	Lower-middle income country	2018, 2020–2023 (5 years)
Burundi	Low-income country	2017, 2019, 2022–2023 (4 years)
Brazil	Upper-middle income country	2021–2023 (3 years)
Jamaica	Upper-middle income country	2020, 2022–2023 (3 years)
North Macedonia	Upper-middle income country	2019–2020, 2023 (3 years)
Indonesia	Lower-middle income country	2022–2023 (2 years)
Pakistan	Lower-middle income country	2022–2023 (2 years)
Uzbekistan	Lower-middle income country	2022–2023 (2 years)

Source: Global Innovation Index Database, WIPO, 2023.

2 Historical background

In this section, a brief historical context of developing countries is reviewed in relation to STI. This is done to explain the diversity in developmental pathways in the regions. At the earlier section, the importance placed on science, technology, and innovation in developing countries is a recent trend, but the discussions on its importance have been present for some time but in the different manner. This section clarifies how the nature of discussion on STI changed over the history.

The origins of universities and public research institutions in many developing countries date back to the colonial periods. Many higher education institutes were established by the colonial government and became national institutions after the country gained independence in the 1960s. At that time, these countries needed to build foundation of newly established state and quickly deal with many social agendas such as food shortages, poor medical systems, and inadequate infrastructure, among others. The countries needed not only financial support but also technological support (technology transfer) to solve the challenges they were facing.

(1) Discussions in international institutions regarding technology transfer

The lack of scientific and technological capabilities in developing countries and the need for support in building such capabilities were considered an urgent matter; however, such awareness was not translated into implementation of necessary policy and investment towards R&D. In fact, according to the Sussex Manifesto (1970), all developing economies accounted for only 2% of global R&D expenditures at the time, compared with the United States (70%) and other advanced economies (28%).[4] Further, the breakdown of R&D expenditures by advanced economies during this period was nuclear power (7%), space (15%), defense (29%), economy (26%), and welfare (22%), with only 1% of total investment directed toward solving country-specific problems (OECD, 1967). In other words, neither developing nor advanced countries were spending sufficient resources on R&D to meet urgent challenges in developing countries. In particular, developing countries needed not just the amount of spending but dealing with the challenge of building indigenous scientific and technical capacity through technology transfer from advanced economies.

The difference in views on the ways to support developing countries—giving aid vs. supporting capacity building—especially with regards to scientific and technical capabilities between developing and advance countries became more and more evident. The Declaration for the Establishment of the New International Economic Order (NIEO), adopted by the United Nations General Assembly in 1974, is one of the illustrations. This declaration clearly stated that support for developing economies by advanced economies should be “trade not aid,” and that the developing countries were once again calling on advanced economies to promote industrialization, agricultural production, finance, and the technology transfer necessary for

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[4] Excludes centrally planned economies.

these activities in order to revitalize the economic activity. In other words, many developing countries considered that advanced economies were providing insufficient support for their development process. Many developing countries hence, argued importance of advanced countries to pay attention to the importance of generating economic activity, fair trade opportunities, and technology transfer in developing countries under the NIEO.

Above claim of developing countries toned down in the 1980s due to debt crisis that was triggered by the oil shock in 1973. The oil shock deteriorated the fiscal balance of developing countries, due to sluggish growth in imports by the advanced economies leading to the gradual accumulation of debts in developing economies. These economies were required to accept debt deferrals from international financial institutions (IMF/WB), placing them in the weak negotiation position. The recovery process of these countries is different country by country. In the next section to follow, attempts were made to provide overarching picture of the path taken by these countries at the regional level.

Box 1 Sussex Manifesto

The Sussex Manifesto calls for "technology transfer" and the "building of indigenous scientific and technical resources" to contribute to the science and technology policies of developing economies by presenting targets using the following indicators to both advanced and developing economies.

- Increase R&D expenditures in developing economies from 0.2% (at the time) of GNP to 0.5%.
- Advanced economies to provide support (technology transfer, etc.) to promote science and technology in developing economies.
- Advanced economies to use 0.05% of their GNP for science and technology assistance (i.e., official development assistance, ODA) to developing economies.
- Utilize 5% of R&D in advanced economies to solve problems in developing economies.
- Improve dissemination (communication) and access of scientific and technological knowledge to developing economies.

The Sussex Manifesto was originally written by the Sussex Group as a prelude to the United Nations World Plan of Action for the Application of Science and Technology to Development (1970). However, certain aspects, such as introducing key performance indicators to evaluate the achievement for both developing and advanced economies, were very advanced for that time. The Manifesto was not approved by the UN as the part of main document, instead, it was eventually added as an annex.[5] This also shows that science and technology in relation to developing countries was highly contested topic, especially on the nature of support. The similar contention regarding the SIT was also observed recently in the negotiation process of selecting 17 SDG goals. The issues supported by the developing economies

[5] The authors of the Sussex Group, which included Chris Freeman, who was a leading expert in science policy research, and Hans Singer, who was a leading expert in development economics, disagreed with this treatment and published the Sussex Manifesto. https://steps-centre.org/wp-content/uploads/bell-paper-33.pdf (Last accessed September 27, 2022)

emphasized the scientific and technical resources as a means for development (e.g., Goal 9), while advanced economies had focused more on solving the ongoing issue.

(2) Science and technology policies in developing economies

From the 1960s, developing economies experimented with policies for promoting technology transfer and building indigenous scientific and technical capabilities. Policy outcomes depend on a country's history, geography, political conditions, and availability of resources, and the results vary by region. In this section, I explain the general background of each region.

A. African countries

Many African countries gained independence in the 1960s and enjoyed steady economic growth at the start. These countries hoped that science and technology could solve the problems they face, as can be seen in the founding speech of the Organization of African Unity (OAU) (see Box 2).

Box 2 Expectations for science and technology in Africa

> "We shall accumulate machinery and establish steel works, iron foundries and factories; we shall link the various states of our continent with communications; we shall astound the world with our hydroelectric power; we shall drain marshes and swamps, clear infested areas, feed the undernourished, and rid our people of parasites and disease. It is within the possibility of science and technology to make even the Sahara bloom into a vast field with verdant vegetation for agricultural and industrial developments".

The passage, from the speech given by then-President Kwame Nkrumah of Ghana at the foundation summit of the Organization of African Unity held in Addis Ababa on May 24, 1963, shows the hopes that African countries had for using science and technology to achieve future development. A statue of President Nkrumah is located at the African Union headquarters building. This passage is also featured on the first page of Science, Technology and Innovation Strategy for Africa 2024.

This attitude towards STI in Africa changed with the shift in economic situation due to the 1973 oil shock. The rapid rise in oil prices not only directly dealt a major blow to economies in the African region but also destabilized the countries as they were dependent on resource exports. The development plans implemented did not suit the new situation, and advanced economies decreased their imports due to their own economic downturns. Furthermore, as the oil money from oil-producing countries, concentrated in advanced economies, were loaned out to African countries, regardless of whether the governments would be able to repay. This resulted in the accumulation of debts in African countries in the 1970s. When interest rates rose worldwide in the 1980s, African were unable to repay their debts and countries fell into debt crises.

The World Bank and the International Monetary Fund (IMF) came into financial support for these countries. In condition, they implemented structural adjustment programs, which encouraged debtor countries to implement fiscal austerity measures as a condition of debt restructuring. These programs imposed strict fiscal austerity, trade liberalization, and promotion of privatization of state-owned enterprises. These policies said to have caused a slowdown in domestic investment, increasing unemployment among civil servants, and worsening poverty.[6] Furthermore, the fiscal austerity measure had impacted the investment in the science and technology fields with the reduction of public spending on higher education and research institutions. It is said that during this period, the African countries under invested in STI areas and lost opportunities to develop human resources with knowledge and capacity.[7]

Of course, African countries were not ignoring the importance of science and technology in the 1980s. The Organization of African Unity advocated for the important role of science and technology in solving problems in Africa (food and water shortages, environmental concerns, productivity improvement) in the Lagos Plan of Action for the Economic Development of Africa (1980), Kilimanjaro Declaration (1987), Khartoum Declaration (1988), and Abuja Declaration (1989); these plans set a goal for R&D expenditure to be 1% of GDP (Iizuka et al., 2015). However, many African countries experienced a period of political and economic instability due to the debt crisis during the 1980s and 1990s, so few measures were implemented. The inability to invest in scientific and technological infrastructure over a long period of time, combined with a weak industrial base, resulted in limited opportunities for economic development. For this reason, a strong push for higher education as well as science and technology in the African Union (AU) must wait until in the 2000s (see Box 3).

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[6] In response to these criticisms, the IMF and the World Bank launched the Heavily Indebted Poor Countries Initiative in the 1990s as well as the Multilateral Debt Relief Initiative and Jubilee Debt Campaign in 2005, and at the G8 meeting, debt relief was implemented in which 100% of the debts of indebted African countries were forgiven.

[7] This statement is based on several secondary sources given that there are no comparable data. Babaloa et al. (1999) compared educational expenditures in Nigeria and Zambia by educational level (elementary, middle, and high school) under structural adjustment, where they found that expenditures in higher education for these countries decreased under structural adjustment but that the reduction was greater for secondary education. Meanwhile, according to the World Bank (1991) "Universities in Africa: Strategies for Stabilization and Revitalization," university enrollment rates were reported to have increased by 61% in the 1980s under structural adjustment. However, expenditures per student were reduced by 70%, access to library books was reduced by 80%, teacher salaries were reduced by 30%, and quality of education declined. Under austerity, countries such as Ethiopia, Ghana, Nigeria, Sudan, Uganda, and Zambia experienced a deterioration in the treatment of highly skilled personnel at universities and public research institutions, with investment in research dropping from an already small base level to less than 1% of the budget, and half of the personnel involved in research went overseas (Saint, 1992). Similarly, the African Development Bank Group's (2008) "Strategy for Higher Education, Science and Technology" reported that over a 20-year period, aid to Africa prioritized primary education, and no support was given to higher education. The African Development Bank began supporting higher education in 1999, but that support is still relatively low (26.6% for primary education, 23.3% for secondary education, 35.3% for TVET, 10.3% for higher education, and 5.9% for literacy and non-formal education). In light of this, the African Development Bank (AfDB)'s strategic document (2008) clearly stated that support for higher education as well as science and technology would be strengthened.

Box 3

In **2005**, the African Union[8] created the **S&T Consolidated Plan of Action (CPA)**, which was approved by the Ministerial Council for Science and Technology (AMCOST) in 2007; this created a concrete movement toward science, technology, and innovation policy on the African continent. The three pillars highlighted here are **1) capacity development, 2) knowledge building, and 3) technology and innovation**.
The African Union declared 2007 as Africa's year for scientific innovations, and set the following goals for 2010, with a 7-year commitment to improve the state of science, technology, and innovation policy through R&D programs: (1) target R&D expenditures at 1% of GDP, (2) establish science and technology centers of excellence, (3) restructure African universities, and (4) provide ST&I indicators via ASTII (African Science, Technology and Innovation Indicators) initiatives.
In 2014, the Science, Technology, and Innovation Strategy for Africa 2024 (STISA 2024) was formulated by the AU. The six priority areas listed in the Science, Technology, and Innovation Strategy for Africa (STISA) were as follows.

1. Eradication of hunger and achieving food security
2. Prevention and control of diseases
3. Communication (physical and intellectual mobility)
4. Protection of our space
5. Live together–build the society
6. Creation of wealth

The above goals have commonalities with Africa's 2063 Development Plan and the SDGs. These also show the shared awareness that science, technology, and innovation should be at the core of national development.

Source: AU, STISA 2024

Until around the 2000s, science and technology policy targeted mainly higher education, universities, and research institutions, but the scope has gradually expanded to include ICT and innovation. Such broadening of coverage towards innovation can be observed with increasing number of African governments starting to formulate strategies and plans on STI related areas in the 2010s (Iizuka et al., 2015). Building centers for higher education and R&D and determining how to utilize those output to support business and solve problems have become a focus of the policy (AfDB, 2008).

In general, the provision of science and technology indicators (R&D, patents, etc.) in African countries (except for South Africa) is considerably lagging behind of OECD countries. While it is difficult to measure the status of STI in Africa, some of the new products and services, based on emerging technologies, are being introduced in Africa at faster rate than in advanced countries due to absence of restrictive rules and the presence of high social needs. Some of the iconic examples in Africa are: M-PESA, payments methods by mobile phones in Kenya and Zipline, transport of medical products by drones in Rwanda. These

[8] The Organization of African Unity was replaced by the African Union in 2002.

examples show that African market, with abundance of social challenges, offers a new window of opportunity to enable technological leapfrogging through path breaking innovation with emerging technology, that is clearly different from the catching-up pathways through reverse-engineering, observed in the East Asia. There are still only a few examples, but if these were able to scale up, these may result into major technological transformation in Africa. Of course, realizing such transformation requires the well-functioning innovation system in which policies, universities and research institutions, and companies (including domestic and foreign startups) are coordinated effectively.

B. Latin American countries

Latin American countries have started to implement various policies to promote technology transfer and build indigenous scientific and technical capabilities even before Africa. In this section, import substitution industrialization policy is taken up as a representative example. In the 1960s, many developing economies were resource-dependent, where primary products were exported, and industrial products were imported. This resulted in the negative spiral of current accounts and trade imbalances due to deterioration in terms of trade and price fluctuations of commodities, which in turn made it difficult for domestic companies to invest in technological R&D to become competitive, making the country increasingly reliant on imports for high-value-added manufactured goods. The aim of the import substitution industrialization policy was to escape from such negative spiral. Specifically, this involved making domestic industries internationally competitive by means of policy—setting up high tariffs and giving subsidies to domestic firms—to "temporarily" protect domestic companies from international competition (i.e., "protection of infant industries") until they are equipped with international competitiveness.

Many Latin American countries introduced this policy in the 1950s and 1960s,[9] and some Asian countries followed the suit. A key aspect of this policy was to improve the competitiveness of the country's industries in a short period of time, by "temporarily" protecting from international competition through policy means. However, once this artificially "guaranteed market" was given to the domestic companies, it was extremely difficult to motivate the domestic firms to make upfront investments in R&D while the protective policy increased government spending until the end of "temporary" period. The difficulty of the import substitution industrial policy was how to phase out the "temporary" protection period and soft-land. In many countries, policy was introduced without this end strategy. As a result, many countries experienced fiscal deficits due to expanded public expenditure while the competitiveness of domestic companies was not being achieved. Hence, the import substitution industrial policy, combined with the debt crisis in the 1970s, is the primary cause of following decade in Latin America being referred to as the "lost decade" (Meller, 1990).

[9] There is also the theory that it was introduced around 1930. Prebisch, 1950.

Starting from the 1990s, many Latin American countries started to pursue economic liberalization, following the successful example of East Asia. These countries implemented a series of policies, such as lowering tariffs, liberalization, privatization, export promotion, inviting foreign direct investment, and establishing special export zones. This improved the economic growth rate, but liberalizing the economy in a short period of time further weakened the countries' already weak manufacturing sector, resulting in increased dependence on the export of primary products (with the exception of Mexico, which had established an export processing zone). The resource boom that began in the 2000s further strengthened the economic system's dependence on primary products. For escaping from the "resource curse", it is considered critical to build value-added manufacturing and service industries at the upstream and downstream end of natural resource based industries by applying the science, technology, and innovation (Crespi et al., 2020; Marin et al., 2015; Pietrobelli et al., 2023). The importance of upstream and downstream industry development policies is particularly discussed in countries that are currently producing mineral ores, such as copper and nickel as well as lithium and critical minerals, which are necessary to produce electric vehicles (EVs) (Pietrobelli et al., 2023). Approaching in strengthening the value chain in mining sector is necessary for dealing with emerging technology and this may present the opportunity for natural resource based countries in the Latin America.

C. East and Southeast Asian countries

Asia includes several regions (East, Southeast, South, and West), comprising countries with diverse social, economic, and cultural backgrounds. In this section, East and Southeast Asian countries are discussed. These two regions are selected due to deep historical and economic ties with Japan. The economic ties with these countries developed, especially after the 1960s, when Japan experienced increasing the sophistication of industrial structures. With the technological maturity, Japan started to transfer low value segment of manufacturing processes to Asian countries (i.e., the newly industrialized countries (NICs) of Hong Kong, South Korea, Taiwan, and Singapore) with labor cost advantages, thereby creating the division of labor in the manufacturing industry in the 1980s. Japan actively provided technology and investment alongside this expansion of production sites.

What enabled these East Asian countries to improve their technological capabilities is via implementing active policy to support for catching up technical capabilities at national and corporate levels. For example, companies of these countries were able to upgrade through absorbing external technology (absorptive capacity) by reverse engineering to meet the demands of the export market. The process of catching up was seen in the cases in which the firms progressively went through from OEM (Original Equipment Manufacturers) - ODM (Original Design Manufactures) - OBM (Original Brand Manufactures), for instance[10] (Hobday, 1995; Kim, 1997; Lee and Lim, 2001). The gradual development of technological capability in East Asian countries was supported by government and company efforts.

In the 1990s, the high growth rates of East Asian countries may have been due to export-oriented industrialization policies leveraging the global demands; these policies were compared with those in Latin American countries, whose economies experienced a slowdown due to government-led import substitution industrialization policies. The World Bank had given a spot light on East Asian economic growth, which by leveraging export markets and foreign investment, maintaining macroeconomic balance, and introducing the principle of market competition, using the term “East Asian Miracle”. The “East Asian Miracle” developed a debate on economic growth, centering on “market vs. government” focusing on the market forces (World Bank, 1993). The discussion, however, did not provide a deep insight on corporate efforts and government interventions that enabled the transfer and building of technological capability in East Asian countries.

Following East Asian countries, the Southeast Asian countries, also achieved economic growth through exports and foreign capital, but caught in the “middle-income trap”, the situation in which the country cannot sustain long-term economic growth. The reasons behind these countries unable to break away from the middle-income status is considered as lack of technological capabilities (World Bank, 2019). The technological capabilities require: (1) sophistication of production and employment, (2) promotion of technological innovation, and (3) shifting of educational systems from acquiring new skills to creating new products and processes (innovation). These aspects of technological capability have been the core at the catching up discussion even before the discussion “middle income trap” (Bell and Pavitt, 1995). At the same time, advantage in focusing on short cycle technology, emerging technology, is to effectively capture the windows of opportunity for technological catching up which are considered important in escaping from the Middle income trap (Lee and Malerba, 2017, etc.). The current era is referred to as the Fourth Industrial Revolution, and many fundamental technologies (mobility, energy, finance, etc.) are considered as emerging technology. This underlines the increasing interests in scientific and technological capabilities and policies among developing countries.

The developmental stages of developing economies of Africa, Latin America and East and Southeast Asia were discussed from the perspective of STI policy. At the beginning of the text, the increasing presence of developing economies in science, technology, and innovation activities while the increasing disparity among the countries in the levels of STI was mentioned. This section aimed to provide some explanations of diversity by presenting some historical perspective.

[10] Examples of these technological capabilities in Asia have been demonstrated by Lin Su Kim, Alice Amsden, Robert Wade, Mike Hobday, and many other researchers. Technological capability in developing economies will be discussed later.

Of course, each geographical region is composed of diverse sets of countries. Even within the same region, countries have different policies, resources, and industrial structures; thus, this section describes only a surface of general trends in the regions. There are increasing number of studies from the STI perspective on developing countries. Please use these materials to deepen knowledge of country-specific development on science, technology, and innovation policy.

3 Main discussion thus far

The question of "how to build innovation[11] (technological) capability" had been a central theme in research on science, technology, and innovation in developing economies. This is because innovation (technological) capability is considered as the main source of competitiveness and improving this capability may enable developing economies to catch up economically to advanced economies. Improving the innovation (technological) capability of developing economies requires (1) technology transfer and (2) building of indigenous scientific and technical resources. The policy interventions thus far have focused on achieving these two aspects. In recent years, scientific and technical resources have also played an important role in solving social agenda. The understanding of innovation capability is understood from much broader perspective than just access to knowledge. It is an ability to exercise the knowledge into application.

Why is innovation (technological) capability considered necessary in the development process? In the mainstream economics, prescription for developing countries has been maintaining the macro and micro balances through decreasing trade deficits, and debt had been the main concern for economies of developing countries.

Abramovitz (1986) is one of the early scholars who argued that "social capability" determines a country's growth, illustrating main components of capability as quality of government institutions, the efficiency of the legal and political system, the presence of social norms that support cooperation and trust, and the ability of a society to adapt to changing conditions. Later, Lall (1992) added the concept of technological "capability", which he further separated into national-level capabilities (NTC) and firm-level capabilities (FTC). These two capabilities are further: FTC includes investment processes, production processes, and linkages (see Table 3), and national technological capability and NTC includes infrastructure, human resources, and technological effort. Lall then posited that the improvement of technological capability is brought about by the interaction of technological capability at the national and firm levels (Lall, 1992).

[11] Innovation (technological) capability: "Technological capability" is often used academically, but here, "innovation capability" and "technological capability" are used as synonyms based on Bell (2009).

Table 3. Innovation (technological) capability matrix

		Investment process		Production process			
Degree of complexity		Pre-investment	Project execution	Process engineering	Product engineering	Industrial engineering	Linkages within economy
Basic	Simple, routine (experience-based)	Prefeasibility and feasibility studies, site selection, scheduling of investment	Civil construction, ancillary services, equipment erection, commissioning	Debugging, balancing quality control, preventive maintenance, assimilation of process technology	Assimilation of product design, minor adaptation to market needs	Workflow, scheduling, time-motion studies, inventory control	Local procurement of goods and services, information exchange with suppliers
Intermediate	Adaptive, duplicative (search-based)	Search for technology source, negotiation of contracts, bargaining suitable terms, information / systems	Equipment procurement, detailed engineering, training, and recruitment of skilled personnel	Equipment stretching, process adaptation and cost saving, licensing new technology	Product quality improvement, licensing and assimilating new imported product technology	Monitoring productivity, improved coordination	Technology transfer of local supplies, coordinated design, science, and technology links
Advanced	Innovative, risk (research-based)		Basic process design, equipment design and supply	In-house process innovation, basic research	In-house product innovation, basic research		Turnkey capability, cooperative research and development, licensing own technology to others

Source: Based on Lall, 1992

The case studies of Korean and Taiwanese companies (manufacturing companies) were conducted to understand the process of acquiring technological capabilities in these two countries that underlines the remarkable growth during the period between 1980s–1990s. The studies showed that the acquisition of technology by developing economies did not start from R&D, as in advanced economies, but rather through the process of "reverse engineering," where they engaged in "learning by imitating" others (companies) and adapting what they learned to their own production system and market conditions. This was a form of improving capability through incremental innovation, in which developing economies first participated in the manufacturing process in some way, learned while manufacturing, improved their technological level, gained competitiveness, and finally manufactured products that they designed (branded) themselves. In other words, these studies proposed that technology absorption and adaptability played more important roles than R&D in the early stages for developing economies when catching up, fully utilizing the systemic capability in mobilizing the resources (e.g., Hobday, 1995, 2003; Kim, 1997).

It has also become clear that technological capability comprises a very complex skill set (see Table 3). The technological capability is defined as "the ability of firms to develop and use new technologies, and to absorb and adapt technologies developed elsewhere." Such capability requires knowledge, skills, experience and institutional structures and linkages, within firms, among firms and outside firms (Bell and Pavitt, 1995). The successful catching up stories of East Asian countries support the above understanding by confirming the need for broad capability for catching up. Indeed, these countries, by implementing effective policies, were able to stimulate technology transfer from external to promote local production leveraging foreign direct investment by multinationals so that domestic firms can learn by exporting.

Research on the technological capabilities of developing economies has since been conducted within the framework that encourages collaboration between governments, companies, universities, and other parties for the purpose of technology transfer and dissemination, called a national innovation system (Freeman, 1987; Lundvall, 1992; Nelson, 1993). In particular, the innovation systems of developing economies are considered different from those of advanced economies, with the former suffering not only from a lack of technological capability, human resources, and infrastructure but also from systemic vulnerabilities, particularly a lack of coordination capability, policy continuity, and weak links between R&D and companies (Arocena and Sutz, 2000). Therefore, research is being conducted on whether and how these vulnerabilities can be overcome.

4 Future science, technology, and innovation in developing economies

The increasing presence of developing economies today is not limited to economic activities; instead, it extends to the fields of science, technology, and innovation. Additionally, "developing economies" consist of diverse sets of countries, and the same can be said for the level of science, technology, and innovation. Despite being different, these countries share common key question: that is "how to build innovation (technological) capability?"

In particular, the process of acquiring technological capabilities in developing economies is greatly influenced by the country's unique experience. For example, the improvement in technological capability did not necessarily begin with R&D but developed through the process of "reverse engineering," where companies engaged in "learning by imitating" others (companies) and adapting the lessons to their own production system and market conditions. Therefore, policy examples from advanced economies cannot be applied to developing economies without the understanding of unique features in developing economies.

In addition, it is states, companies and systems that learn science, technology, and innovation, and the studies have been conducted based on unique features in developing economies.

There are emerging types of innovation that are applicable for solving social problems that are specific to developing economies; for instance, the inclusive innovation for alleviating widening disparities. Under the era of digitalization and the Fourth Industrial Revolution, there are many examples—such as application of mobile money in Kenya, MPESA, or transport of medical products by drone in Rwanda, Zipline— where innovative product and services to solve social issues were introduced in Africa before advanced economies. This is because the need for solution is greater in Africa while there are lower institutional barriers for introducing innovation. In other words, developing countries can be an interesting seedbed for innovation. Indeed, some countries are taking interesting strategy using this feature. For example, Rwanda is seeking to become a digital nation and is implementing the regulatory sandbox for digital innovation, welcoming startups from the world to pilot proof of concepts. These are limited examples but show what can be possible in the future.

Science, technology, and innovation indicators were not fully available to show the progress made in developing countries, and much of the knowledge comes from the case studies. In recent years, these indicators have begun to be compiled in an internationally comparable format, and there are expectations that comparative analyses based on more detailed evidence will be conducted to understand the situation and the process of building technological capabilities in these countries. The unique context of innovation in developing countries are also showing new possibilities to advanced economies. The knowledge on innovation in these sectors, for example, the methods for measuring innovation in the informal, agricultural and mining sectors, could benefit not just developing and also advanced countries.

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