Chapter 8

Innovation Systems and Digital Transformation

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Introduction

When you hear the word 'innovative', what comes to mind? You may think of a firm providing products or services by making full use of state-of-the-art technologies such as artificial intelligence (AI) or a firm producing such technologies. Innovation is a key growth factor not only for firms but also for nations. Innovative firms generate more value added than non-innovative firms. The more innovative firms there are in an economy, the more qualitative products and services are provided to the market with a more efficient method of production, which means the better the living standards (income levels) the people living in the economy enjoy. An innovative nation or economy has an environment conductive to generating innovative firms. It has highly competitive universities attracting talented people. It generates many start-ups, and venture capitalists gather there. When looking at innovative economies, we find that systematic linkages exist between universities, firms, investors, and related organisations. This finding applies not only to established developed countries like the G7 members, but also to newly developed countries like the Asian Miracles – the Republic of Korea (henceforth, Korea), Taiwan, Singapore, and Hong Kong.

This chapter discusses optimal innovation systems at the macroeconomic level for middle-income Association of Southeast Asian Nations (ASEAN) Member States (AMS). As an introduction, we give a brief overview of the discussion. Many AMS are middle-income countries, and their technology utilisation levels are much lower than those of high-income advanced countries such as the United States (US). Economic growth theory implies that closing this technology utilisation gap is a primary way of turning middle-income countries into high-income countries as quickly as possible. For middle-income AMS to improve their technology utilisation levels, they need to understand the mechanism of technology adoption – both at the firm level and at the macroeconomic level – and build their innovation systems by harnessing digital transformation.

Many AMS have advanced to middle-income status by participating in global value chains, based on their comparative advantage in labour costs amid globalisation. More precisely, AMS have improved their income levels by attracting foreign direct investment (FDI) to manufacturing plants through competitive multinational enterprises by providing low-cost labour resources. Moreover, indigenous firms that trade with global firms have improved their productivity through learning effects. It may appear that this growth model is sufficient for economies to grow to high-income levels since advanced technologies are likely to flow to AMS through FDI, typically in the manufacturing sector. However, what we have observed is the middle-income AMS struggling with overcoming the 'middle-income trap'. In examining the differences between Asian Miracles cases and economies that remain at middle-income levels, it is difficult to find economies that have reached high-income levels through FDI alone. All the Asian Miracles that succeeded in establishing innovation systems, building innovation capabilities, and fostering competitive private firms in their countries did so by developing a healthy competitive market environment.

For middle-income AMS to develop innovation-friendly markets, they need to keep in mind the lessons from empirical studies regarding technology diffusion from global frontier firms to national firms. First, promoting global-level firms in a country benefits other national firms – although national laggers seem to have difficulty adopting technologies directly from global frontier firms. Second, fostering global-level firms requires encouraging entrepreneurship, FDI for global innovative enterprises, an improved educational system, research and development (R&D) activities, industry–university R&D partnership, and an effective intellectual property rights system. Third, minimising inefficient and incapable firms contributes to improvements in macro-level innovation capabilities. To do so, it is necessary to balance the benefits of employment protection and costs of employment allocation inefficiency regulations and to reduce administrative costs for businesses. Last, to help national laggers catch up, product market laws and employment protection must be relaxed and industry–university R&D cooperation must be encouraged.

From the perspective of indigenous firms or start-ups hoping to be global-level innovative firms in their economies, it is difficult for them to avoid competing with global frontier firms in high-tech industries, such as electronics, machinery, pharmaceuticals, aerospace, transport equipment, software, information technology (IT), and science and technical services. Competitive firms in both the Asian Miracles – Hong Kong, Korea, Singapore, and Taiwan – and China undertook creative imitation innovation strategies, and can provide lessons for latecomer firms competing with advanced firms in high-tech industry markets. Creative imitation is an innovative activity in which latecomers try to partly imitate and adapt new products and services from abroad to satisfy local market demands or to create lower-cost versions to compete in price-sensitive markets. It is an important option for firms in the middle-income AMS.

Another important point in the promotion of innovative firms is full utilisation of digital transformation. The Asian Miracles succeeded in reaching the technological frontier before or around the 1990s, before the information and communication technology (ICT) revolution started in full swing. The current digital transformation trend has changed the importance of start-ups relative to incumbent firms in innovation compared with the Asian Miracle era. The significance of start-ups has been a major driver of innovation, especially in sectors such as e-commerce, mobile applications, finance, and the internet of things.

ICT, or digital technology, has a property of general-purpose technology (GPT): it will be deployed in all sectors – both manufacturing and non-manufacturing – and make current business models obsolete. The digitalisation tide never turns, so both the private and public sectors in AMS economies must advance by shifting weight from accumulated 'incremental' innovation (typically in the manufacturing sector) to 'disruptive' digital innovation (adopted in all sectors). Technology utilisation gaps embody the potential to grow quickly by catching up with and even leapfrogging to a higher development stage – through the 'advantage of backwardness'.

To do this, AMS governments must keep in mind that supporting firms arbitrarily will not help to create innovative firms. Such industrial policies are not justified either theoretically or empirically. Pro-innovation industrial policies should keep the market competitive and impose strict accountability. In addition, AMS governments should establish innovation systems in which a government organisation oversees and coordinates the formulation and implementation of innovation policies across several government departments. They should also provide monetary incentives to the private sector, including local and international firms, to invest in R&D for innovation. Moreover, they should promote university–industry cooperation (UIC), which is an important component of innovation ecosystems that foster technological diffusion and knowledge spillover.

This chapter is organised as follows. Section 2 breaks down productivity gaps into three factors – reproducible capital, human capital, and total factor productivity (TFP) – amongst AMS, East Asian countries, and the US. Section 3 claims the importance of TFP in economic growth by using macroeconomic models. Section 4 shows the movements of TFP of AMS and East Asian countries in recent decades. Section 5 explains the relationship between TFP and innovation capability, and shows what the 'advantage of backwardness' is via macroeconomic modelling. Section 6 presents a mathematical expression of macro-level innovation capability as the aggregation of individual firm-level innovation capability, and discusses empirical findings on technology diffusion from global frontier firms and national firms. Section 7 explains that digital technology has the nature of GPT and discusses empirical findings regarding the relationship amongst digital technology adoption, firms' capability, and market incentives. Section 8 discusses optimal innovation systems, harnessing digital transformation, for middle-income AMS to conclude this chapter.

Breakdown of Productivity Gaps Amongst AMS and East Asian Economies

A firm's innovativeness and productivity are closely interrelated. Let us consider two business firms: an innovative firm and a less innovative firm. It is easy to imagine that the innovative firm providing attractive goods and services at affordable costs can sell or produce more than the less innovative firm, even using the same capital and labour inputs. In this case, the innovative firm is more productive than the less innovative firm – meaning that the former's output (sales or production) is larger than the latter's using the same amount of inputs. At the macroeconomic level, similar things happen. An innovative economy is more productive than a less innovative economy. This section sees the history and current state of productivity gaps amongst AMS and East Asian economies at the macroeconomic level. The interpretation of productivity as innovativeness will be discussed later.

'Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker' (Krugman, 1997: 3). This quotation is by Paul Krugman, the Nobel Prize-winning economist, in 2008. Economic researchers often quote it to summarise the importance of productivity growth in a nation's economic development. Here, we break down the labour productivity of AMS into several factors by conducting a development accounting exercise. We show that productivity comprises the following three factors: TFP, physical capital to human capital ratio, and human capital per worker. We also discuss the implications of economic growth theory on how middle-income countries can grow to high-income countries.

Economic growth theory often models gross domestic product (GDP) as the following production function:

$$Y = AF(K,H) = AK^{\alpha}H^{1-\alpha}, \tag{1}$$

where Y is output (GDP), A is TFP, K is physical capital (e.g. production machinery), H is human capital, and α is a parameter that takes a value more than zero and less than one. This parameter equals the share of capital compensation under the competitive market assumption. This production function is intuitive. An economy produces output by inputting reproducible capital and human capital. These two types of inputs are aggregated through the Cobb-Douglas type function F. The aggregation multiplied by TFP is the economy's final output. One can interpret TFP as a productivity parameter in terms of using both physical and human capital. That is why it is called 'total factor' productivity. Human capital covers a broad kind of inputs provided by humans, consisting not only of hours worked but also of workers' skills obtained through education or training. Human capital is modelled as the product of the average skills of workers obtained through education and the total hours worked. Rearranging Equation 1, one has

$$\frac{Y}{L} = A\left(\frac{K}{H}\right)^{\alpha}\frac{H}{L},$$

where L is labour input measured in total hours worked. This equation means that labour productivity (Y/L) is composed of TFP, the physical to human capital ratio to the power of capital share, and the human capital per labour unit. We assume the capital share parameter is one-third, following Jones (2016). TFP itself is not observable. Therefore, TFP is calculated by dividing labour productivity by the physical to human capital ratio to the power of capital share and by the human capital per labour unit.

Table 8.1 reports the results of the development accounting exercise for the AMS and East Asian countries in 2019 based on the associated data from the Penn World Table version 10.0 (University of Groningen, Groningen Growth and Development Centre, n.d.).[2] All the figures represent the values relative to those of the US. For instance, in the labour productivity (Y/L) column, Cambodia has a value of 0.047, which means that Cambodia's labour productivity is 4.7% that of the US. In the research on economic growth, the US is considered to have grown for the past century at the production frontier (Jones, 2016). Therefore, one can interpret the values in the table as each economy's gap from the global production frontier.

As claimed by Paul Krugman, each country's relative labour productivity level is associated with its income level, or GDP per capita (Krugman, 1997). The World Bank classifies countries into low-income, lower-middle-income, upper-middle-income, and high-income economies.[3] According to the classification list of the World Bank (n.d.), Cambodia, India, the Lao People's Democratic Republic (Lao PDR), Myanmar, the Philippines, and Viet Nam are classified as lower-middle-income economies. China, Indonesia, Malaysia, and Thailand are ranked as upper-middle-income economies. Brunei Darussalam, Japan, Korea, and Singapore are classified as high-income economies. It is evident that a country's income level is correlated with its labour productivity. We use low- (high-) income economies and low- (high-) labour productivity economies interchangeably.

[2] Table 8.1 reports two types of productivity measures. TFP is based on hours worked. Because of data limitations, the table does not report Brunei Darussalam or the Lao People's Democratic Republic (Lao PDR). TFPE is based on workers. The main text only discusses TFP. TFPE is reported for interested readers.

[3] See World Bank (n.d.).

One of the notable findings from Table 8.1 is that the range of TFP is wider than the other two factors. The smallest value in the TFP column is Cambodia's (0.212). The smallest value of physical to human capital ratio to the power of α is also Cambodia's (0.422). The smallest value of human capital per unit of labour is Myanmar's (0.472). Another finding is that if a country is a low-income economy, it tends to have low TFP, a low physical to human capital ratio, and low human capital per unit of labour. In other words, there are no observations that have the combination of a high TFP, a low physical to human capital ratio, and a low human capital per unit of labour. Lower-income countries, such as Cambodia, Myanmar, and Viet Nam, have a significantly low TFP, physical to human capital ratio, and human capital per labour unit. Conversely, high-income countries, such as Singapore, Japan, and Korea, have high values of these three factors.

Table 8.1 Development Accounting for the AMS and East Asian Countries (US = 1, 2019)

Country	Y/L	TFP	$(K/H)^{\alpha}$	H/L	Y/L_E	TFP_E	$(K/H_E)^{\alpha}$
Brunei	.	.	.	0.746	1.075	1.026	1.404
Cambodia	0.047	0.212	0.422	0.524	0.066	0.265	0.472
Indonesia	0.160	0.341	0.769	0.610	0.183	0.373	0.804
Lao PDR	.	.	.	0.518	0.116	0.362	0.616
Malaysia	0.335	0.502	0.811	0.821	0.417	0.581	0.873
Myanmar	0.070	0.284	0.500	0.492	0.097	0.353	0.558
Philippines	0.135	0.338	0.551	0.724	0.166	0.388	0.590
Singapore	0.740	0.672	0.949	1.161	0.977	0.808	1.041
Thailand	0.206	0.378	0.729	0.748	0.244	0.423	0.772
Viet Nam	0.091	0.258	0.462	0.765	0.110	0.293	0.492
China	0.158	0.341	0.642	0.720	0.194	0.392	0.688
India	0.118	0.330	0.616	0.579	0.141	0.373	0.655
Japan	0.578	0.617	0.977	0.959	0.553	0.600	0.963
Rep. of Korea	0.552	0.581	0.947	1.004	0.620	0.627	0.983
US	1.000	1.000	1.000	1.000	1.000	1.000	1.000

AMS = ASEAN Member States, ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product, TFP = total factor productivity, US = United States.

Notes: H/L = human capital per hours worked, $(K/H)^{\alpha}$= reproducible capital–human capital ratio to the power of capital share, $(K/H_E)^{\alpha}$ = reproducible capital–human capital ratio to the power of capital share by using only the number of workers, TFP_E = TFP calculated by using only the number of workers, Y/L = GDP per hours worked, Y/L_E= GDP per worker.

Source: University of Groningen, Groningen Growth and Development Centre (n.d.).

Why an Economy's Capital Stock Level and its TFP Move Together in a Correlated Way

The theory of economic growth accounts for these two findings with a simple dynamic macroeconomic model called the Solow or Solow–Swan growth model (Solow, 1956; Swan, 1956). This growth model (hereafter the Solow growth model) suggests that if an economy has low TFP, it also has a low physical to human capital ratio. In other words, low levels of TFP are the potential root cause of low living standards for low-income countries. Further, an extended Solow growth model can show that a low TFP economy also has a low human capital per labour unit. Here, we describe the model and solve it to explain the mechanism whereby TFP determines the physical to human capital ratio. Readers who are not interested in the mechanism can skip the rest of this section.

The Solow growth model has a simple setting, with no trade with foreign countries and a constant saving rate. It specifies the macro-level physical capital accumulation as follows:

$$K_{t+1} = I_{K,t} + (1 - \delta_K)K_t, \tag{2}$$

where K_t is the physical capital stock at time t, $I_{K,t}$ is the gross investment in physical capital at time t, and δ_K is the depreciation rate of physical capital. Further, the model assumes that the amount of gross investment at time t is determined by the constant fraction (saving rate) of output (GDP) as follows:

$$I_{K,t} = s_K Y_t = s K_t^{\alpha} (AH)^{1-\alpha}, \tag{3}$$

where s_K is the constant saving (investment) rate for physical capital. Note that we slightly modify the production function (1) with TFP placed inside the parentheses of labour input to obtain a simple solution for the model. Additionally, we assume that TFP and human capital grow exogenously at a constant rate. Solving the dynamic model composed of Equations 2 and 3 for K_t, one has the following steady-state ratio of physical to human capital multiplied by TFP:

$$k_t^* \equiv \left(\frac{K_t}{AH}\right)^* = \left(\frac{s_K}{\delta_K}\right)^{\frac{1}{1-\alpha}}. \tag{4}$$

As seen in the above solution, k^*_t is determined solely by the saving rate, depreciation rate, and the capital share parameter. Accordingly, when the TFP is low, the physical to human capital ratio is also low. Conversely, when the TFP is high, the physical to human capital ratio is also high. Thus, the solution of the Solow growth model implies that the TFP is the root cause of the low capital stock level.

The Solow growth model can be easily extended to a growth model with endogenous human capital. We replace the production function with the following:

$$Y_t = K_t^{\alpha} H_t^{\beta} (AL)^{1-\alpha-\beta}, \tag{5}$$

where β is a parameter that satisfies $0<\beta<1$ and $\alpha+\beta<1$. We assume that human capital accumulates in a similar way to reproducible capital (Equation 2), as follows:

$$H_{t+1} = I_{H,t} + (1-\delta_H)H_t, \tag{6}$$

where $I_{H,t}$ is the gross investment in human capital at time t, and δ_H is the depreciation rate of human capital. Gross investment in human capital is also determined in a similar way to physical capital investment, as follows:

$$I_{H,t} = s_H Y_t \tag{7}$$

where s_K is the constant saving (investment) rate for human capital. Now, the growth model with endogenous human capital comprises Equations 2, 3, 5, 6, and 7. Solving this model, one has the following solutions for the ratio of reproducible capital to hours worked multiplied by TFP and the ratio of human capital to hours worked multiplied by TFP:

$$k_t^{**} \equiv \left(\frac{K_t}{AL}\right)^{**} = \left(\frac{s_K}{\delta_K}\right)^{\frac{1-\beta}{1-\alpha-\beta}} \left(\frac{s_H}{\delta_H}\right)^{\frac{\beta}{1-\alpha-\beta}},$$
$$h_t^{**} \equiv \left(\frac{H_t}{AL}\right)^{**} = \left(\frac{s_K}{\delta_K}\right)^{\frac{\alpha}{1-\alpha-\beta}} \left(\frac{s_H}{\delta_H}\right)^{\frac{1-\alpha}{1-\alpha-\beta}}.$$

It is evident that if TFP is low, the steady-state human capital per labour unit is also low. Therefore, the growth model with endogenous human capital indicates that if an economy has low TFP, it has a low reproducible capital per labour unit and a low human capital per labour unit.

Does international trade change the result? The answer is 'no' if we disregard the role of international trade in helping economies to improve their TFP. Suppose there are two economies: one is North, and the other is South. We assume that North's TFP is higher than South's. The condition of free trade and capital flows across these countries equalises the return on physical capital in North and South. In a competitive market, the return on physical capital equals the marginal productivity of physical capital (MPK). When considering the production function in Equation 3, one has the following equalisation condition:

$$MPK^N = MPK^S \Leftrightarrow \alpha\left(\frac{K^N}{A^N H^N}\right)^{\alpha-1} = \alpha\left(\frac{K^S}{A^S H^S}\right)^{\alpha-1} \Leftrightarrow \frac{K^N}{A^N H^N} = \frac{K^S}{A^S H^S}.$$

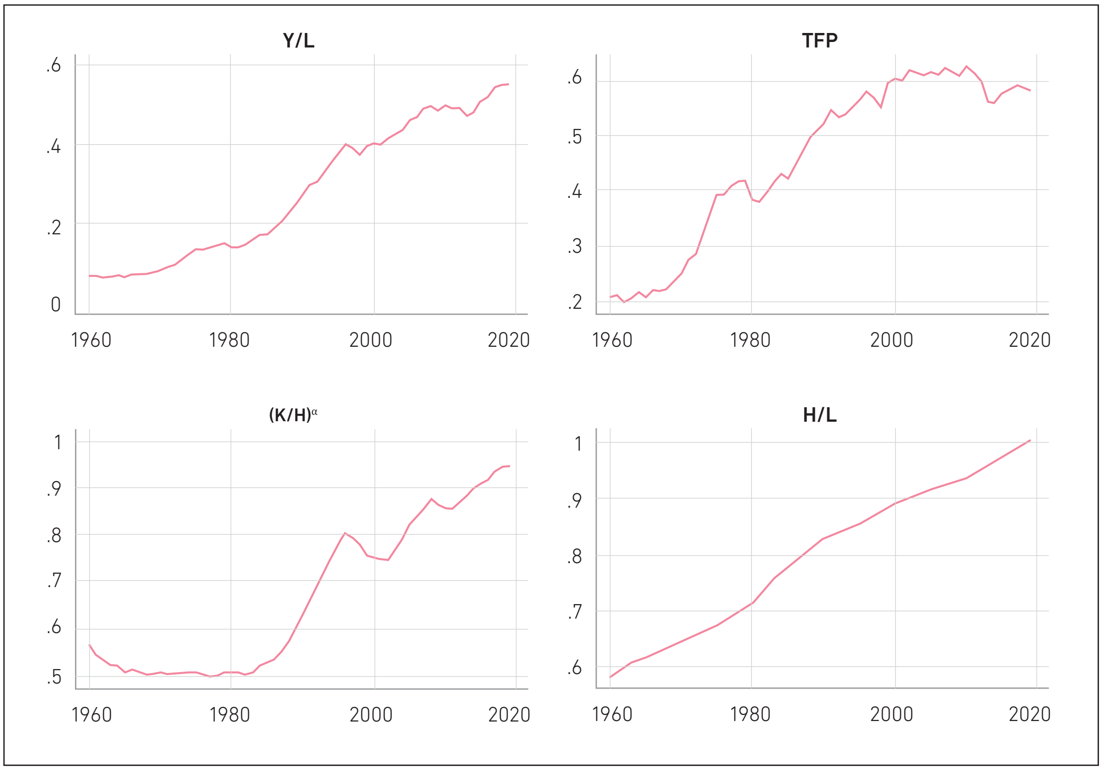
This equation clearly shows that North's physical to human capital ratio is larger than South's. Therefore, low-income economies with low TFP cannot accumulate capital stock to the level of high-income countries, or improve their living standards solely by depending on resources from foreign countries.

It should be noted that the discussion here does not deny that a small, less industrialised economy can improve its living standards by changing its industrial structure through incorporation in the global economy. As Ventura (1997) discussed, based on his economic growth model incorporating the Heckscher-Ohlin model of international trade, a small, less industrialised country can develop its economy by accumulating capital stock and changing its industrial structure from labour-intensive to capital-intensive. The country is small, so it can export as many capital-intensive goods as possible at a price determined in the global market.[4] This is a good way of describing the high economic growth of small export-oriented East Asian countries after World War II. However, it can only apply to such transition economies. If the economy's scale reaches a non-negligible level in terms of influence on global supply, the economy can no longer enjoy the non-decreasing international price.[5] Further, as seen in Figure 8.1, even Korea (a representative country of the East Asian Miracles) caught up towards the production frontier not only in capital stock accumulation but also TFP and human capital accumulation. Therefore, improvement in TFP is still essential for low- and middle-income economies to improve their living standards towards high-income economies.

[4] If the economy is closed, it will face diminishing returns on capital-intensive goods as it accumulates capital stock. In an economy with no international trade, accumulation of reproducible capital means that its scarcity value decreases relative to labour.

[5] See Acemoglu (2009: 648–91).

Figure 8.1 Republic of Korea's Productivity Gap and Its Breakdown Since 1960 (US = 1)



GDP = gross domestic product, TFP = total factor productivity, US = United States.

Notes: H/L = human capital per hours worked, $(K/H)^{\alpha}$ = reproducible capital–human capital ratio to the power of capital share, Y/L = GDP per hours worked.

Source: University of Groningen, Groningen Growth and Development Centre (n.d.).

TFP of AMS and East Asian Countries in Recent Decades

As shown above, Korea is representative of the countries that succeeded in turning low-income economies into high-income economies. It succeeded in turning the trend towards the frontier around the beginning of the 1970s. After that, its physical to human capital ratio began to move towards the US level around 1990. Human capital was constantly moving towards the US level from 1960 and caught up with and surpassed the US in 2019.

Let us examine the movement of other countries' TFP since 1985 (Figure 8.2). Singapore has experienced fluctuating movement of the TFP gap, but its overall level has remained closer to the frontier than that of the lower-income countries since 1985. The other high-income countries – Japan and Korea – have also experienced higher TFP movements than lower-income countries since 1985.

Malaysia, one of the higher middle-income countries, has experienced TFP movements at about 50% of the US level since 1985. It is evident that Malaysia's TFP distance from the frontier is farther than that of the high-income countries.

The TFP gap of Indonesia, another higher middle-income country, was relatively close to the frontier (like Malaysia) before 1998. However, its TFP level dropped suddenly in 1998, and the widened TFP gap has not shrunk significantly since then. Thailand is also categorised as a higher middle-income country, and experienced a similar movement of TFP to Indonesia, even though the drop in the TFP level was more moderate than that of Indonesia.

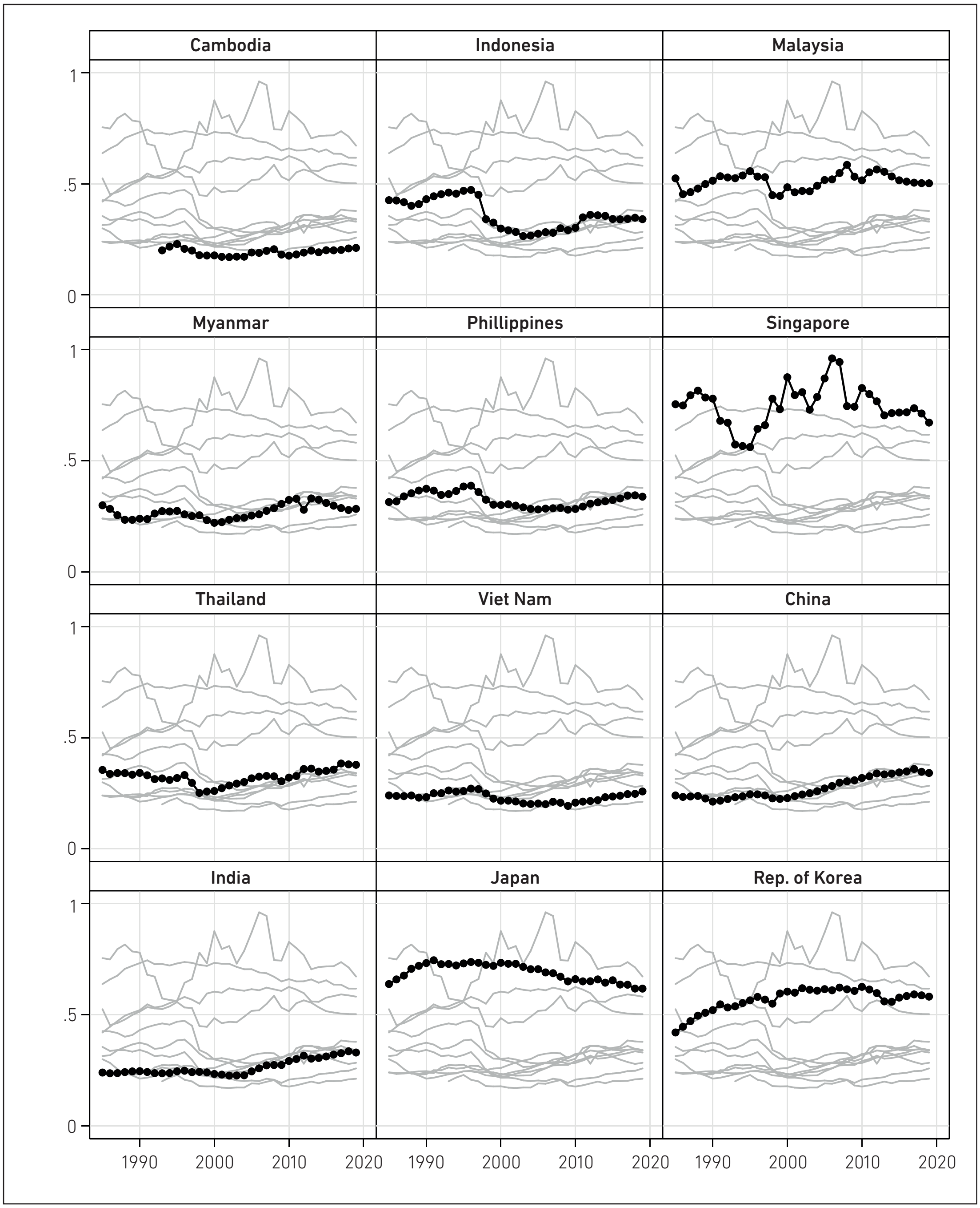
China, the last higher middle-income country, was a low TFP country in East Asia. However, the TFP level started moving towards the frontier around 2000. The current TFP level is close to the frontier, at almost the same level as Indonesia and Thailand.

India experienced a similar movement pattern of the TFP gap to that of China. India's TFP remained at a very low level before 2005. However, TFP started moving towards the frontier in 2006, and the TFP level is slightly lower than that of the higher middle-income countries.

Myanmar follows India in terms of the recent distance of TFP from the frontier. Viet Nam follows Myanmar – its TFP level is low, but the recent movement of the distance to the frontier has started shrinking steadily. Cambodia's TFP remains the lowest amongst the countries examined here since the 1990s.

Taken together, while some of the lower and higher middle-income countries show signs of a trend towards a decreasing TFP gap, many of them remain at a significantly lower level.

Figure 8.2 TFP Level at Current PPP Since 1985 (US = 1)



PPP = purchasing power parity, TFP = total factor productivity, US = United States.

Source: University of Groningen, Groningen Growth and Development Centre (n.d.).

TFP, Innovation Capability, and the Advantage of Backwardness

So far, we have explained the importance of TFP for improving economies' living standards. We defined TFP as a productivity parameter in terms of using both physical and human capital. As we mentioned, TFP is not observable. In the growth theory context, TFP is a 'measure of our ignorance' (Abramovitz, 1956: 11) in the sense that a large portion of economic growth and income level cannot be accounted for by directly measurable physical and human capital inputs. Although it is impossible to measure directly, growth theory provides a way to gain economic insights from TFP – the stock of technology available to produce output with physical and human capital inputs. Now, the production function (Equation 1) implies that products and services are generated by a combination of technology, physical capital, and human capital.

In the economic growth theory context, the stock of technology is also called the stock of codified knowledge or ideas. A typical example is scientific knowledge. Product blueprints and food recipes are familiar examples. People can access and use technology without preventing other people from using it.[6] In contrast, human capital is implicit knowledge because it can only be used by the person who has (learned) it in their brain, and other people cannot use it. Technology at its frontier is the worldwide stock of codified knowledge.

Technology is codified knowledge. It follows that technology would be available anywhere in the world because of its nature. However, as seen above, there are significant differences in TFP levels between low- and high-income countries. Moreover, some countries have caught up or moved towards the frontier, while others are far from the global frontier. These results imply that the existence of technology is different from the utilisation of technology. In other words, an economy's available technology stock can be different from the technology frontier. Additionally, its capability of adopting or adapting to the stock of technology can be different amongst economies.

Innovation, the theme of this chapter, is an increment in the utilisation of technology. More concretely, a particular economy's innovation is defined as implementing the technology stock that the economy has not utilised to provide new products and services (product innovation) or improve productivity in providing existing goods and services (process innovation).[7] Thus, the innovation capability of a particular economy refers to the capability

[6] In economics terms, it is called non-rivalry.

[7] The Oslo Manual (OECD/Eurostat, 2018: 20) defined it thus: 'an innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)'. Note that the Oslo Manual is an international reference guide for national statistics organisations in charge of measuring innovation or people interested in innovation study.

of implementing new technology. It should be noted that generating new technology (codified knowledge) is an invention, not innovation.[8] Innovation is the implementation or deployment of new technology in the economy.

The capability for innovation determines the technology level available in an economy. Further, there is an 'advantage of backwardness' for less advanced economies. We show the reason for those claims by using a mathematical model of technology differences across economies.[9] Suppose there is a particular economy, country i, with its technology stock less than the frontier.

$$\Delta A_{i,t} = \sigma_i\left(A_t - A_{i,t}\right) + \lambda_i A_{i,t}\,, \tag{8}$$

where A_t is the stock of technology at the global frontier, $A_{i,t}$ is the stock of technology available in country i (national frontier), and $\Delta A_{i,t}$ is an increment in country i's technology from t to $t+1$. The technology absorption parameter σ_i takes a positive value and stands for country i's capability of absorbing advanced technology that exists outside the country but which the country did not have. Meanwhile, the country can innovate on its own based on its stock of technology at the rate λ_i. The term $\lambda_i A_{i,t}$ can be interpreted as completely new technologies that go to part of the next-period global technology stock,[10] A_{t+1}, or already existing technologies in the global stock, A_t. We assume that λ_i takes a positive value that is less than the technology growth rate at the frontier, g. Rearranging Equation 8, one has

$$(1+g)\Delta a_{i,t} = \sigma_i - (\sigma_i + g - \lambda_i)a_{i,t}\,,$$

where $a_{i,t}$ is the ratio of country i's technology stock to the frontier technology stock, $A_{i,t}/A_t$. This dynamic equation implies that there exists a steady state of country i's relative technology ratio, such that

$$a_i^* = \frac{\sigma_i}{\sigma_i + g - \lambda_i}\,. \tag{9}$$

This solution shows that even if a particular economy cannot increase its technology stock by itself, or $\lambda_i=0$, only if the absorption parameter is positive, the economy's technology grows at the frontier growth rate g. Further, Equation 9 indicates that a particular economy's technology stock ratio compared with the frontier technology stock depends on its capability of absorbing advanced technology from outside the economy

[8] It should also be noted that for advanced economies producing at the frontier, the creation of new technology means innovation since the implementation of the created new technology is interpreted to happen simultaneously.
[9] See Acemoglu (2009: 611–47) for more details on this model.
[10] In this simple model, even in that case, $\lambda_i A_{i,t}$ will not affect the dynamism of A_t (the global technology stock is assumed to be exogenous).

and its capability of innovation by itself based on its technology stock. This finding also shows that even if $\lambda_i=0$, when σ_i is large, the relative technology stock ratio can be close to one. These phenomena can be called the advantage of backwardness, which cannot be expected for advanced economies producing at the global frontier.

As we have seen above, most AMS have significant gaps with the global technology frontier. Generating completely new technologies and implementing them is important to reduce the gap. However, if AMS cannot leverage the advantage of backwardness, it is almost impossible for them to catch up with the global frontier quickly. The next section discusses possible determinants of innovation capability, mainly through technology adoption.

Macro-Level Innovation Capability as an Aggregation of Firm-Level Innovativeness

Until the previous section, we depicted an economy as one large firm that produces output (GDP) by using the whole economy's physical capital and human capital resources. Here, we break down the macro-level innovation capability into an aggregation of individual firms' innovativeness. Not unexpectedly, firms are diverse in terms of available technology and innovativeness. To make the story simple, products and services (Y) are created by combining available technology (A) and labour input (L). As shown below, the macro-level available technology can be expressed as the weighted average of an individual firm's available technology (A_j): [11]

$$A = \frac{Y}{L} = \frac{\sum_j Y_j}{\sum_j L_j} = \sum_j \left(\frac{L_j}{\sum_j L_j}\right)\frac{Y_j}{L_j} = \sum_j w_j A_j \text{, where } \sum_j w_j = 1\,. \tag{10}$$

Further, for simplification, we assume that there are two types of firms: national frontier firms (NF) with higher available technology and national lagger firms (NL) with lower available technology. Equation 10 becomes

$$A = w_{NF}A_{NF} + w_{NL}A_{NL}\text{, where } A_{NF} > A_{NL} \text{ and } w_{NF} + w_{NL} = 1. \tag{11}$$

Equation 11 implies that there are two ways to increase the macro-level available technology: a rise in an individual firm's available technology (a rise in A_{NF} or A_{NL} or both) and a rise in the weight of the NF firm (a rise in w_{NF}). The former is called a within-firm effect, and the latter a composition effect (Bartelsman and Dhrymes, 1998). The latter effect is important in the sense that the discussion based on the macro production

[11] This input-based weighted average of individual productivity (available technology) is adopted by Bartelsman and Dhrymes (1998), although it is not exactly the same definition. The output-based weighted average is also often used in the literature (e.g. Foster, Haltiwanger, and Krizan, 2001).

function until the previous section did not explicitly deal with the effect. The composition effect can be considered as the extent to which an economy efficiently allocates its economic resources across firms in the economy.

Similar to the macro-level technology adoption modelling in the previous section, we introduce globally innovative firms, called global frontier firms (GF), which run businesses at the global frontier by fully utilising the globally available stock of technology. Then, from GF to NF and/or NL, technology diffusion (or transfer) can occur through the NF and NL learning and/or imitating activities to catch up to the frontier. The empirical literature regarding technology diffusion has studied the extent of the within-firm and composition effects for countries; and Andrews, Criscuolo, and Gal (2015) showed the following findings based on a cross-country firm-level data set for the Organisation for Economic Co-operation and Development (OECD) countries:[12]

1. There tends to be an order of technology diffusion amongst GF (the highest firm group in productivity in the data set), NF, and NL. First, advanced technologies diffuse from GF to NF. After that, the technologies transfer from NF to NL.
2. The macro-level productivity gap between countries tends to be accounted for by not the within-firm effect but the composition effect. Specifically, the gap between GF and NF is relatively small, but the weight (or scale) of NF, compared with GF, is small in lower productivity countries.
3. GF, compared with non-GF, tend to have the characteristics of operating on a larger scale, generating more profits, having a younger age, being part of multinational conglomerates, and being more patent-intensive. GF selection is very competitive. Around half of them drop from the GF group after a year, and less than 15% can keep the GF position after 5 years.
4. The within-firm productivity gap between GF and NF tends to decrease when the quality of education systems is higher, R&D tax subsidies for small and medium-sized enterprises (SMEs) are more generous, and there is more R&D collaboration with universities. The gap also tends to decrease when venture capital is abundant. Regarding patent protection, there is non-linearity between its extent and the gap. The stronger the protection, the smaller the gap when the industry is more R&D intensive. Meanwhile, stronger intellectual property rights protection leads to a larger GF–NF gap when the industry is more entrepreneurial (having a higher firm turnover rate).
5. The composition (scale) gap between GF and NF tends to decrease when employment protection is less strict, administrative burdens on start-ups are lower, business closing (bankruptcy) costs are lower, and R&D tax subsidies for SMEs are not more generous.
6. The within-firm productivity gap between NF and NL tends to decrease when product market regulations are less strict, employment protection is less strict, and R&D collaboration with universities is higher.

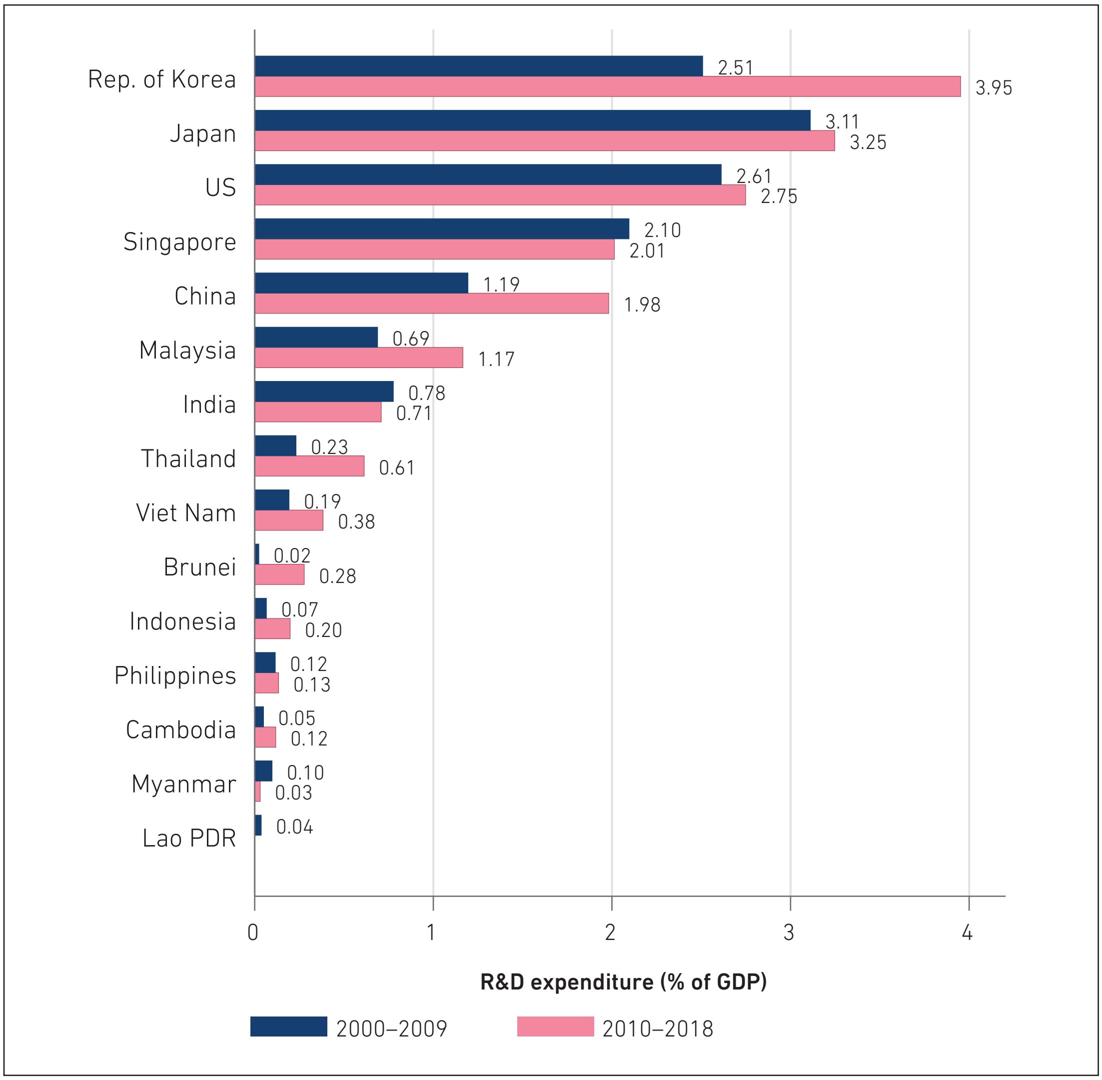
[12] The data set covered non-farm to non-financial industries from 2001 to 2009.

Note that these findings are based on OECD countries – high-income countries – but there are similar findings in the literature. For example, Iacovone and Crespi (2010) used firm-level data for Mexico, a middle-income country, and found that Mexican firms tend to catch up with the national frontier more quickly than the global frontier.

We can take many lessons from the above findings. First, if we want to improve the innovation capability of NL, we should take measures to increase NF innovativeness at the same time (Finding 1). In other words, fostering global-level firms in a country, even if there are not many, can positively affect other national firms. Second, to cultivate global-level firms, we should prioritise stimulating entrepreneurship, attracting FDI for global innovative firms, improving the education system, promoting R&D activities, encouraging UIC in R&D, and setting up an appropriate intellectual property rights system (Findings 3 and 4). Third, we need to reduce the share of inefficient, incapable firms to gain macro-level innovation capability (Finding 2). To do so, we should balance employment regulations with lower administrative burdens on entrepreneurs (Finding 5). Last, to help less capable national firms to catch up, we should keep product market regulations and employment protection lenient and promote UIC in R&D (Finding 6). We need to keep these findings in mind when planning innovation policies.

Several findings of Andrews, Criscuolo, and Gal (2015) have indicated that R&D activities play an important role for national firms in catching up to more innovative firms. R&D activities are considered to contribute not only to discovering completely new knowledge or the technology and innovation based on it, but also imitating or adopting technologies generated by others (Griffith, Redding, and Van Reenen, 2004). Even for imitation, some tacit knowledge is required, and it is difficult to be codified or obtained without investigation. Let us examine some data to see the status of AMS R&D activities. Figure 8.3 shows R&D expenditures as a percentage of GDP for AMS and East Asian countries. According to the figure, the R&D expenditures of many AMS have been very small, even taking into consideration the small size of their economies. AMS R&D expenditures as a percentage of GDP have been less than 1% on average since 2000. Although most AMS increased their scale of R&D from the 2000s to the 2010s, the scale of R&D in AMS except Singapore and Malaysia was significantly smaller than that of advanced economies. Of course, firms' innovation activities are not limited to R&D, and R&D tax incentives for SMEs may cause a negative impact on national innovation capability through composition effects (Finding 5). However, we should keep in mind that all AMS struggling with the middle-income trap have significantly lower R&D expenditure rates than high-income countries.

Figure 8.3 R&D Expenditures by AMS and East Asian Countries
(periodic average, % of GDP)



AMS = ASEAN Member States, ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product, R&D = research and development, US = United States.

Source: World Bank (2022), World Development Indicators. https://databank.worldbank.org/source/world-development-indicators (accessed 23 February 2022).

To conclude this section, we underscore the significant potential impact of reducing the number of inefficient firms. In fact, there is a significant capability gap between large-scale companies and SMEs in middle-income AMS compared with advanced economies (OECD, 2021). Additionally, OECD (2021) pointed out that one of the explanatory factors for the productivity gap is the FDI in large firms in AMS from advanced economies. More concretely, the FDI enables large firms to access productivity-enhancing technology and resources. These facts suggest that for middle-income AMS to catch up to advanced economies in terms of technology, they need to enhance the innovation capability of indigenous firms. Furthermore, while increasing entry and exit rates, incubating innovative entrepreneurs, or start-ups, is significant.

Characteristics and Adoption of Digital Technology

In the previous section, we discussed macro-level innovation capability through the lens of the adoption of non-specific technologies – technologies in general terms. Here we focus on digital technology adoption. As pointed out by Kretschmer (2012), digital technology, or ICT, has a unique property compared with other technologies as it impacts a wide range of industries and economic activities. Due to these characteristics of digital technology, it is considered a GPT, coined by Bresnahan and Trajtenberg (1995). Bresnahan and Trajtenberg set forth three more concrete characteristics that GPTs need to have:
1. Pervasiveness – GPTs must be utilised in almost all sectors.
2. Improvement – the cost of GPTs must continuously decrease as time passes.
3. Innovation spawning – GPTs must promote product and process innovations.

In the context of this chapter, the first and third properties – pervasiveness and innovation spawning – are important. As Kretschmer (2012) illustrated by taking an ICT user firm's case, firms leveraging ICT can improve their productivity by communicating speedier than before with suppliers and distributors, streamlining business processes, and reducing inventories. Further, firms can make better decisions, cut more coordination costs, and reduce the number of supervisors, through more prompt and extensive conveyance of information. In the sector of information goods (e.g. books, music, and computer software), decreased communication and replication costs have brought disruptive business model innovation to the market.

One of the reasons that the economic growth literature focuses on ICT is the macro-level productivity growth gap between the US and Europe after the mid-1990s. Both economies experienced almost the same productivity gains in the ICT-producing sectors (e.g. semiconductors and computers), but the US experienced significantly larger productivity gains than Europe in the ICT-using sectors – mainly market services, including distribution, financial, and business services (van Ark, O'Mahoney, and Timmer, 2008). Regarding these findings, Bloom et al. (2012) showed that the ICT intensity (ICT capital stock per hours worked) of the US is also significantly larger than that of the Europe, and asserted that the US firms' flexible people management practices, which are complementary to ICT capital, contribute to the ICT-using productivity gains.

Andrews, Nicoletti, and Timiliotis (2018) studied if there were significant differences in digital technology (cloud computing, enterprise resource planning, and customer relationship management) adoption rates at the industry level caused by firms' capabilities and the market environment (incentives) by using cross-country industry-level data for OECD countries. They found:

1. There is a statistically significant positive relationship between the penetration of high-speed broadband and digital technology adoption.
2. In knowledge-intensive sectors, more organisational capital such as management abilities is linked with higher levels of digital technology adoption.
3. The ICT competence level of the working-age population, the provision of ICT training (on the job or during the job), and the efficient matching of workers' skills to jobs contribute to higher digital technology adoption.
4. Three market incentives – a flexible labour market, competitive pressures, and risk capital availability – have positive effects on digital technology adoption.

From the perspective of the policymakers responsible for innovation policy, Andrews, Nicoletti, and Timiliotis (2018) gave us important insights. The first finding suggests that digital infrastructure needs to be well developed to promote digital technology adoption. While AMS continue to improve their digital connectivity, the development is uneven – with large gaps between and within countries (Chen and Ruddy, 2020). Improving digital connectivity is indispensable for AMS to leverage digital technology. The second and third findings imply that firms' internal managerial resources (management skills) and external human capital resources (ICT-skilled labour) are essential for digital transformation. Digital technology is complementary to management skills and ICT-skilled labour, so improving the quality of education from the elementary to university level is essential. The fourth finding suggests that AMS should keep developing a healthy market competition environment.

Innovation Systems Harnessing Digital Transformation

In the above sections, we saw the innovation capability gap between advanced economies and AMS which struggle with the middle-income trap, and discussed the significance of the adoption of technology from the global frontier and the essential factors for promoting the adoption of technologies, especially digital technology. In the last section, we discussed policy implications from a systematic view of innovation at a macro level (country or economy) by considering several actors related to innovation activities in the economy – incumbent firms, start-ups, universities, and public research institutes.

In the literature, the systematic view of innovation at the macro level is called a 'national' innovation system (Freeman, 1987).[13] However, as Soete, Verspagen, and ter Weel (2010) pointed out, the 'national' concept may have been undermined because an innovation

[13] The concept of a national innovation system was established in the late 1980s by Christopher Freeman based on a study of Japan's miraculous post-war growth (Soete, Verspagen, and ter Weel, 2010).

system is shifting from a national one to an international one.[14] In contrast to each nation's domestic efforts in research and knowledge accumulation, worldwide economic growth since the 1990s has been brought about by an acceleration in technology diffusion across countries. The rapid spread of ICT globally has undoubtedly contributed to more rapid penetration of leading technologies. Although we consider that a 'national' factor still plays a significant role in macro-level innovation capability, we are also of the opinion that the point raised by Soete, Verspagen, and ter Weel is reasonable. Thus, to avoid giving an impression of exaggerating 'national' borders in innovation activities, we call what the existing literature calls a national innovation system simply an 'innovation system'.

The word 'system' implies networks or structured processes for accomplishing a particular purpose where several actors interact with each other. Accordingly, an innovation system is composed of networks or structured processes promoting innovation at an aggregate level where many actors at a micro level interact. In this chapter, we follow the definition of an innovation system presented by Kimura, Wong, and Ambashi (2019: 33): an innovation system is 'a continuous process of systemic change facilitated by government policies (at central and local levels), where institutions, learning processes, and networks play a central role in generating technological advancement and innovation via the intentional, systemic interactions between various components such as universities, institutions, the private sector, and investors'.

Kimura, Wong, and Ambashi (2019) illustrated the interactions between actors in an innovation system (Figure 8.4). As the figure shows, universities and public research institutes (PRIs) play an important role in innovation implemented by incumbent firms and start-ups. They provide trained R&D personnel and technologies to incumbent firms. They also carry out joint R&D with incumbent firms. In addition, they transfer technologies and technology talent to start-ups. Universities and PRIs advance technology and knowledge diffusion in an innovation system.

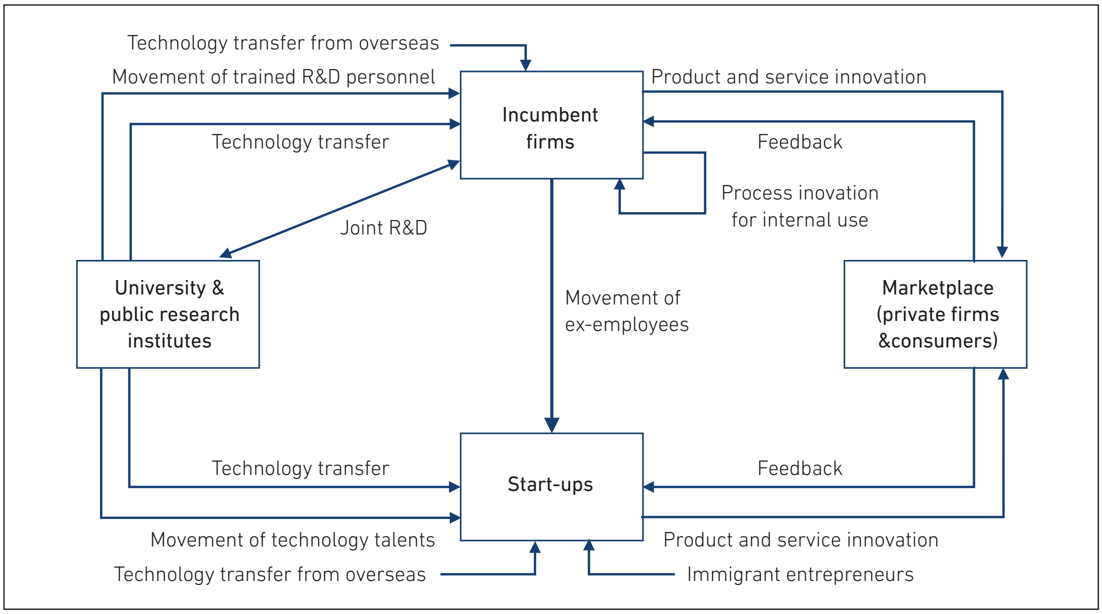
As mentioned in Box 1, during the second unbundling of globalisation, technology transfer from overseas is an important source for incumbent firms to improve their innovation capability. This improvement channel is not only through FDI but also through transactions with advanced foreign firms. Ueki (2020) showed that multinational firms brought technology transfer to Southeast Asian countries both through their subsidiaries and through inter-firm relationships between multinational firms and local firms (e.g. customer–supplier relationships). In addition to the external technology transfer, incumbent firms can carry out process innovation for internal use through learning

[14] As another reason that the national concept has been challenged, Soete, Verspagen, and ter Weel, (2010) asserted the increasing importance of innovation without industrial research, typically in the knowledge service sectors. The old view of innovation systems was based on a simple dichotomy – innovation happens in professional R&D laboratories via R&D and/or learning activities, while production and distribution activities are not relevant to innovation and play a simple role of cost minimisation and sales maximisation. In contrast, what is happening now is more digital-based efficiency improvements and more service-related activities, such as in the financial sector, wholesale/retail sectors, healthcare, education, government services, and business operations.

by doing. Product innovation by incumbent firms is brought about both through R&D activities directed by management and through 'intrapreneurship' – activities performed by employees, motivated by employee entrepreneurship.[15] New products and services created by incumbent firms are provided to consumers through the marketplace, and the incumbent firms build innovation capabilities through success or failure in the market and consumer feedback.

For start-ups, in addition to universities and PRIs, domestic incumbent firms and overseas entities are parts of knowledge and human resources of innovation. A new start-up is founded by university scientists (university channel), ex-employees (incumbent firm channel), or immigrants (overseas channel). Of course, unemployed people may also establish a start-up. A start-up founded by ex-employees can be independent from their ex-employer (independent start-ups) or dependent (spin-offs). Start-ups play a very important role in product innovation: not only do they discover business opportunities through scientific advancement, but they also do so through internal information (e.g. successes or failures in the market and customer feedback) as well as exogenous changes (e.g. demographic transitions, shifts in consumer perceptions, and changes in government regulations or market conditions) (Fukugawa, 2018).

Figure 8.4 Illustration of Interaction Between Actors in an Innovation System



R&D = research and development.

Source: Authors based on Kimura, Wong, and Ambashi (2019).

[15] Fukugawa (2018) gave the following examples of intrapreneurship: SR-71 (Lockheed Martin), the Post-It (3M), Elixir (Gore), the VHS (JVC), autofocus (Konica), the digital camera (Casio), the plasma display panel (Fujitsu), and the PlayStation (Sony).

Although the role of the government is not shown in the figure, as mentioned in the definition of an innovation system, the government organises the entire system of innovation and facilitates dynamic and interactive innovation processes through policies. The remainder of this section discusses important recommendations and the role of government in an innovation system, harnessing digital transformation in emerging AMS economies.

Shift some weight from ‘incremental innovation’ to ‘disruptive innovation’ and leverage the ‘advantage of backwardness’

An important recommendation drawn from the discussion about the third unbundling and latecomer advantages and disadvantages in Box 1 is that AMS should shift some weight from ‘incremental innovation’ to ‘disruptive innovation’, and leverage the ‘advantage of backwardness’. The discussion of the third unbundling in Baldwin (2016) implies that digital transformation will dramatically decrease the cost of the movement of people via virtual means. Further, this digital transformation has the potential to drastically change existing products and services.

The third unbundling is brought about by further advancement in ICT than we saw in the second unbundling. ICT comprises IT and communication technology (CT) (Kimura, Shrestha, and Narjoko, 2019). AI, robots, data processing, and machine learning are examples of IT that can be used for everything from marketing, research, design, and industrial processing to inventory management.[16] CT refers to technologies that connect people even if they are far away from each other – exemplified by the internet, smartphones, and the 5G network. CT promotes the local and international division of labour as well as the dispersion of economic activities. Significant decreases in business-to-consumer (B2C) and consumer-to-consumer (C2C) transaction and communication costs create new businesses. Accordingly, IT and CT will be adopted in and spread to most sectors.

For instance, Kimura, Shrestha, and Narjoko (2019) pointed out that advancement of the adoption of ICT may change traditional sectors, including the agricultural sector. Using smartphones, farmers can obtain accurate information about markets, soil quality, and weather, as well as use sensors to monitor their crops and sell directly to customers over the internet. By reducing waste, improved inventory management will reduce the cost of manufacturing and distributing perishable agricultural goods. Self-driving tractors may also be used by farmers to harvest crops more swiftly and effectively. This example tells us that the advancement of ICT adoption in the third unbundling will bring about intrinsically more ‘disruptive’ than ‘incremental’ innovation as ICT adoption completely

[16] Box 2 summarises the introduction to Ing and Grossman (forthcoming).

transforms existing industries. Taking the same agricultural example, farmers, firms that produce agricultural equipment, or start-ups that provide ICT solution services to other sectors may create a new agricultural production system. Consequently, AMS need to acknowledge that it is inevitable to shift some weight to 'disruptive innovation' from 'incremental innovation', which had been carried out through FDI and learning through transactions with advanced firms. Many AMS still have technology utilisation gaps, but this means that there is ample room for exploring the 'advantage of backwardness', which enables economies to grow quickly by catching up with and even leapfrogging to a higher development stage.

Regarding disruptive innovation for emerging economies as latecomers, Kimura, Wong and Ambashi (2019) asserted that 'creative imitation' is increasingly important. Creative imitation is an innovative activity whereby latecomers attempt to partially imitate and adapt new goods and services from abroad to meet the needs of the local market, or to produce lower-cost variants to be competitive in price-conscious markets. This innovation strategy is efficient since latecomers do not need to compete directly with first movers, as described in Box 1. This kind of innovative imitation is what China accomplished during most of its catch-up period, even though observers from developed countries have often referred to copycats or intellectual property pirates. However, they are not necessarily exact replicas and often include some degree of originality. For instance, Baidu, a Chinese search engine, did not just replicate Google by offering better internet search tools in the Chinese language. It modified them to search Chinese chat sites rather than just websites. As an additional advantage, creative imitation activities require minimal R&D or patenting. Ideally, as emerging markets climb up the technological ladder, the proportion of creative components relative to imitation components will rise. Middle-income AMS should recognise the importance of creative imitation and take measures to promote it. Creative innovation is mentioned again below.

In encouraging disruptive innovation, it is notable that start-ups play an important role. Sauermann (2018) showed that based on a survey of US R&D employees, start-up employees are more productive in patent applications (a measure of innovation) than incumbent firm employees. Additionally, start-up employees are more motivated, especially in terms of taking risks. Kimura, Wong, and Ambashi (2019) referred to a study showing that the significance of start-ups has been the primary engine of innovation, particularly in areas such as e-commerce mobile apps, fintech, and the internet of things. To foster start-ups, entrepreneurship education programs have a substantial positive effect on students' entrepreneurial involvement (Ho, Low, and Wong, 2014). Therefore, strengthening university education, especially computer engineering and entrepreneurship management programmes, is recommended for many AMS.

Further, one of the policy tools to promote innovative start-ups is the US Small Business Innovation Research (SBIR) program. The SBIR program started in 1982 to generate innovative start-ups by subsidising R&D from the conceptual stage and fostering start-ups by supporting commercialisation. The SBIR program comprises three phases. In the first phase, the government bodies participating in the SBIR, such as the Department of Defense and the Department of Health and Human Services, grant or contract with start-ups for concept development or an early stage of R&D. Each start-up granted SBIR funds will receive $50,000–$250,000 for 6 months to 1 year to support R&D. In the second phase, the government bodies subsidise the start-ups that succeeded in their conceptual research to proceed to the next stage of prototype development. The start-ups generally receive $750,000 for 2 years. In the third phase, the government bodies no longer fund start-ups that succeeded in the second phase, but they support their commercialisation and contracting government bodies procure new products or services from them.[17] Lerner (1999) showed that the start-ups awarded SBIR subsidies experienced higher growth than other firms and more of them attracted venture financing. Additionally, Siegel and Wessner (2012) revealed that the university-based SBIR start-ups experienced better performance than the other start-ups. Amongst AMS, Singapore has a similar programme – Startup SG.[18] For the other AMS, the SBIR program is helpful in considering how to promote innovation by start-ups.[19]

Strategically compete with existing advanced digital platforms

As discussed in Box 1, the current global digital platforms (e.g. Apple, Google, Facebook, and Amazon) enjoy first-mover advantages in a winner-takes-all game. In the context of economics, a platform business such as those digital platforms is called an intermediary in two-sided markets. 'Two-sided' means that the intermediary (platform) has two (or more) groups of users, and when the number of one group increases, the value of the platform to the other group increases (positive externality or network effects), and vice versa (Rysman, 2009). What are the differences between one-sided (non-platform business) markets and two-sided markets? Here is an example of retail businesses. In the case of traditional retail businesses, consumers buy goods directly from a brick-and-mortar retailer (the retailer purchases and stocks goods and sells them to consumers). This is a one-sided market. Meanwhile, in the case of e-commerce platform businesses (e.g. Amazon), consumers purchase goods from suppliers through a virtual marketplace provided by a platform. When the number of consumers increases, the platform becomes

[17] For readers interested in more detail on this subject, see SBIR (n.d.).

[18] See Startup SG (n.d.).

[19] The Government of Japan introduced an R&D subsidiary program for SMEs in 1999, but unfortunately positive policy effects such as speeding up SME growth were not observed (Inoue and Yamaguchi, 2017). Reviewing the program, the government found that there was not enough support for investment in technological seeds and supporting commercialisation, including utilising public procurement. Based on that, the government introduced a new SBIR program reinforming those problems in June 2021. Japan's experience could also be helpful for AMS.

more valuable to suppliers because they can sell their goods to more people through the markets, and vice versa. This case represents two-sided markets.[20] An intermediary of two-sided markets can be considered a monopolist because the intermediary can block the access to its members from other industries, and it competes with other platforms aggressively to enjoy the monopolistic position. Considering the above example, the e-commerce platform businesses compete by imposing no costs on consumers. The winning platform can enjoy a monopolistic position against suppliers and imposes high costs on suppliers to use the platform.

In addition to two-sidedness, economies of scope and scale in data intensify the monopolistic position of first-mover platform firms. Intrinsically, two-sided markets play a role of matching two groups, exemplified by a marketplace matching consumers and suppliers. In digitalised economies, how efficiently platforms can utilise data – in the retail example, how efficiently they can match consumers and suppliers – determines who will win the game. To maximise network effects, platforms require and invest in ambiguous and probabilistic matching technology (Martens, 2020).[21] Economies of scope in data – meaning more variables of data (e.g. consumer profiles and locations) – lead to more efficiency in probability matching. Economies of scale in data – meaning more observations (e.g. the number of consumers collected) – lead to more efficiency in probability matching. Economies of scope and scale in data intensify the monopolistic positions of existing platforms that have already collected a large number of observations and variables. Further, Marten pointed out that algorithms enhance the value of data through a feedback mechanism based on improved predictions and learning by doing. Using these data-driven network effects, global platforms expand their business to new sectors. Simply put, global platforms are incredibly powerful competitors for latecomers. For incumbent firms and start-ups in emerging economies to enter and grow in the markets, AMS need strategies.

To foster local firms in the digital economy, AMS should take into consideration the above first-mover advantages of existing platforms. To this end, it is necessary to support local firms, but governments should not simply help underperforming local firms. It is not rare that local firms fail to improve their market performance despite government assistance. When governments support local firms, they should keep in mind that the market discipline and autonomy of the public sector are important for the success of innovation policies (Cherif and Hasanov, 2019). This point is related to the next recommendation. For local firms and start-ups, creative imitation is an effective strategy to compete with advanced

[20] Readers may think that a traditional brick-and-mortar retailer also has two-sided market properties because a greater number of consumers makes a retailer more attractive to suppliers, and vice versa. Regarding this point, Rysman (2009) said that although all markets have two-sided properties to some extent, whether a market is two-sided is determined by how important the market's two-sidedness (cross-group network effect) is. In the case of a traditional retailer, potential consumers are usually limited to the local area, and the network effect benefitting suppliers is limited. Meanwhile, an online shopping site does not exclude consumers living far from the firm providing the service within the range of logistics availability. In this case, its network effect is significant.

[21] Meanwhile, unambiguous matching requires neither a various nor a large number of observations. For example, matching a consumer who wants a particular product and a supplier that produces the product does not require other consumers' purchasing data.

platforms. For AMS governments, it is essential to support local firms by building the ICT capacity of workers and strengthening the technology diffusion function of universities and PRIs. Further, the governments should develop and maintain a healthy market environment with a flexible labour market, competitive pressures, and the availability of risk capital.

Foster frontier firms in 'sophisticated' industries through 'competition-friendly' policies

In the previous recommendation, we referred to Cherif and Hasanov (2019), who studied the industrial strategies of the Asian Miracles compared with those of the middle-income countries. They concluded that the success of the Asian Miracles is not due to luck, but is the result of implementing a Technology and Innovation Policy (TIP). As a result, the Asian Miracles achieved sustainable high growth by working on an ambitious TIP for decades.

Cherif and Hasanov (2019) presented three approaches to a TIP: (i) the highest gear is the moonshot approach, where governments intervene to remove obstacles to domestic firms investing in 'sophisticated' industries for sustained long-term growth (correction of market failure); (ii) the middle gear is the leapfrog approach, which refers to industrial policies to attract FDI based on comparative advantages; and (iii) the low gear is the snail crawl approach, which is limited to the correction of government failures such as high inflation, unnecessary regulations, uncertain property rights, and other economic distortions by governments. They defined 'sophisticated' products or services as ones that have positive effects on the tradable sector in terms of productivity gains by using them and spillovers through a feedback loop between the two sectors. Sophisticated industries are R&D and patent intensive, exemplified by electronics, machinery, pharmaceuticals, aerospace, transport equipment, software, IT, and science and technical services.

Cherif and Hasanov asserted that the governments of the Asian Miracles set extremely ambitious goals to catch up quickly with advanced economies in terms of both technology and the economy. They summarised the four governments' TIP characteristics as follows: (i) interventions to build new capabilities in sophisticated and tradable industries beyond their current capabilities; (ii) emphasis on export promotion; and (iii) fierce competition in domestic and foreign markets and strict accountability (no unconditional government assistance and no support without fierce competition amongst domestic and foreign firms). Based on the above considerations, Cherif and Hasanov claimed that the economic success of the Asian Miracles was dependent on their moonshot approach. They also argued that the reason that Malaysia has not moved into the high-income country group is because it implemented the snail crawl and leapfrog approaches rather than the moonshot approach.

What we can draw from their study is that AMS governments should take actions to create firms in sophisticated industries to overcome the middle-income trap and to accomplish sustained long-run growth. To this end, governments should be careful about not depending on the unconditional support of local firms and start-ups, but should keep the market competitive and impose strict accountability. Studies other than Cherif and Hasanov (2019) have also claimed that industrial policies that prevent competition and pick winners (and select losers) to support infant industries are inefficient both theoretically and empirically. Aghion et al. (2015) advocated for 'competition-friendly' industrial policies – providing subsidies or tax holidays to competitive sectors (not picking up winners) and strengthening market competition by encouraging the entry of young firms.

Other recommendations for building innovation systems

We conclude this chapter by mentioning other recommendations to build innovation systems by referring to the policy options presented by Ambashi (2018).

The first one is establishing a government organisation to oversee and coordinate the formulation and implementation of innovation policies across several government departments. Even though some AMS have a government organisation responsible for innovation policies, most of them are not comprehensive or systematic. Singapore is an exception. The Government of Singapore's Economic Development Board has consistently promoted technical development, infrastructure, public services, and the provision of incentives and subsidies for FDI. The Economic Development Board's effective management and coordination, in cooperation with the Agency for Science, Technology, and Research (A*STAR), led in the establishment of the biomedical sciences cluster. International pharmaceutical firms, biomedical local firms, start-ups, and venture capital have been promoted. R&D collaboration between universities and the healthcare services sector has been stimulated. AMS should review their own government organisations and move towards establishing ones that can control and coordinate innovation policies.

Second, AMS governments should encourage the private sector, including local and international firms, to spend on R&D for innovation via suitable monetary incentives. To promote R&D via incentives, AMS governments need to assist private firms and PRIs in commercialising their innovations. It is an attractive option to establish specialised PRIs whose primary mission is to conduct R&D and provide technical assistance for commercialising various types of innovation. Local firms often face barriers at the commercialisation stage because of lack of knowledge and expertise. A*STAR in Singapore and Fraunhofer-Gesellschaft in Germany may serve as models.

Last, AMS governments should establish a conductive innovation ecosystem which includes universities, government research institutions, and the business sector. UIC is an important component of innovation ecosystems that foster technological diffusion and knowledge spillovers, and it plays a critical role in many industrialised nations' innovation systems. UIC happens when universities offer consultancy services and licence their technology to industry, collaborate on research projects with them, and foster academic entrepreneurship such as spin-offs and start-ups in exchange for getting research funding from them. As mentioned above, the SBIR program in the US has created university-based start-ups which grow faster than other start-ups. It is worth mentioning that UIC may contribute to regional development efforts spearheaded by local governments. As such, AMS must foster UIC as a viable tool capable of not only enhancing university-based discoveries but also disseminating and commercialising them for the private sector via close regional collaboration. To seize these possibilities, rules and procedures to accelerate UIC must be developed, such as those found in Japan's Basic Law for Science and Technology (1995), Japan's Technology Licensing Organization Law (1998), and the US Bayh-Dole Act (1980). AMS should use these legislative and institutional changes to spread UIC best practices.

Box 1 Latecomer Advantages and Disadvantages in Digital Transformation

For firms in late-industrialising economies to catch up rapidly through innovation, it is not enough to know about the innovation resources such as human capital and accumulated knowledge stocks. It is necessary to know their advantages and disadvantages as latecomers. Compared with early movers (leading companies in industries), latecomers have the following advantages and disadvantages (Wong, 1999). Wong's study was based on the experience of Japan and newly industrialised economies in East Asia, but the concept is still useful as a starting point to discuss what will be changed by the current trend of digitalisation.

The first advantage is that latecomers do not incur the sunk costs that first movers do. When first movers invest in an asset to serve existing customers, they suffer from switching costs in adapting to significant shifts in consumer taste, whereas latecomers have no switching costs to serve new customers.* The second advantage is the same as the first, replacing consumer taste with technology. When a shift in the technology used to supply goods or services renders the first movers' assets obsolete, the first movers incur switching costs. The first and second disadvantages are intensified when first movers have significant organisational inertia. The third advantage is the information externality generated by first movers. Latecomers can learn from the first movers' experience. They can avoid trial-and-error costs, enjoy educated consumers, and learn from existing knowledge and expertise, which lowers latecomers' imitation costs. The fourth advantage is the asymmetric information between latecomers and first movers. Latecomers can observe and study first movers' behaviour, while the opposite is difficult.

Late-industrialising economies give latecomers the following additional advantages. The first additional advantage is the lower cost – at least initially – of a broad variety of resources for providing goods or services, such as labour and labour-intensive inputs. The second additional advantage is that the market is sheltered to some extent from firms in advanced economies. Markets in late-industrialising economies tend to be protected via government regulation or specialised local needs. These obstacles for firms in advanced economies to enter local markets enable local firms to develop their skills without being pressured by advanced firms. The third additional advantage is the amplified information asymmetry between first movers in advanced economies and latecomers in late-industrialising economies. It is likely that advanced firms outside the late-industrialising economies have difficulty gathering information on local adversary firms and their technology sources.

Latecomer Disadvantages

Next are latecomer disadvantages (or first mover advantages). The first disadvantage is the existence of consumer switching costs. First movers capture consumers at an early stage of the market. Subsequently, consumers incur costs by switching from the products or services of first movers to those of latecomers, exemplified by brand recognition and user sunk costs (the time and cost of learning about a new brand). The second disadvantage is that first movers can take pre-emptive actions. Pre-emption is an offensive action by first movers to prevent latecomers from threatening the first movers' position in the market. First movers have a competitive advantage in terms of pre-emptive strategies, exemplified by locking in key resources and predatory investment in capacity. The third disadvantage is the existence of experience or the learning curve effect. First movers have more experience providing goods and services than latecomers. Accordingly, when experience has significant positive effects on productivity (e.g. a market where cumulative research and development (R&D) or the learning-by-doing effect is crucial), first movers have competitive advantages over latecomers. The fourth disadvantage is that first movers are winners in the winner-takes-all race, exemplified in the patent race.

In addition to the generic disadvantages above, the following latecomer disadvantages are present in late-industrialising economies. The first additional disadvantage is the distance from lead users, who have a strong need for new products or services, which indicates the general demand of the future market.** Lead users typically locate in advanced economies. The second additional disadvantage is the distance from the leading sources of technology. The leading technology sources are typically advanced firms, universities, or public institutions in advanced economies. The third additional disadvantage is the scarcity of competitive advanced factors, following Porter (1990). A nation's industrial competitiveness depends on specialised factors (e.g. specific skilled personnel, infrastructure, and knowledge bases) rather than generalised factors (e.g. a highway system and general employees). An advanced private sector is considered significant in building specialised factors. For example, advanced private firms are good at investment in R&D for commercial innovation in new fields or for the needs of particular industries. These advanced private firms are typically located in advanced economies.

The table summarises the discussion above.

Generic and Economy-Specific Advantages and Disadvantages of Latecomers and Late-industrialising Economies Based on Wong (1999)

Advantages	Description
Generic latecomer advantages	
1. Sunk costs for existing consumers	When first movers invest in an asset to serve existing customers, they suffer from switching costs in adapting to significant changes in consumer tastes.
2. Sunk costs for existing technology	When a shift in technology to supply goods or services renders the first movers' assets obsolete, they incur switching costs.
3. Information externality	Latecomers can observe and study first movers' behaviour, while the opposite is difficult.
Latecomer advantages specific to late-industrialising economies	
1. Lower costs for resources	Late-industrialising economies usually have lower costs of resources, such as labour and labour-intensive inputs.
2. Sheltered local markets	Firms in advanced economies find it difficult to enter the markets of late-industrialising economies because they tend to be protected via government regulation or specialised local needs.

Advantages	Description
3. Amplified information asymmetry	Advanced firms outside the late-industrialising economies are likely to have difficulty gathering information on local adversary firms and their technology sources.
Generic latecomer disadvantages	
1. Consumers' switching costs	First movers capture consumers at an early stage of the market. Subsequently, consumers incur costs by switching from the products or services of first movers to those of latecomers (e.g. brand recognition).
2. Leaders' pre-emptive actions	Pre-emption is an offensive action by first movers to prevent latecomers from taking action to threaten the first movers' position in the market. First movers have a competitive advantage to take pre-emptive strategies.
3. Leaders' learning curve effects	First movers have more experience providing goods and services than latecomers (e.g. in a market where cumulative R&D or the learning-by-doing effect is crucial).
4. Winner-takes-all case	First movers are winners in the winner-takes-all race (e.g. patent race).
Latecomer disadvantages specific to late-industrialising economies	
1. Distance from lead users	Lead users have a strong need for new products or services, which indicates the general demand of the future market. Lead users typically locate in advanced economies.
2. Distance from advanced technology sources	Leading technology sources are typically advanced firms, universities, or public institutions in advanced economies.
3. Scarcity of competitive advanced factors	A nation's industrial competitiveness depends on specialised factors (e.g. specific skilled personnel, infrastructure, and knowledge bases). Advanced private firms, which are typically in advanced economies, are important in building specialised factors.

Source: Authors, based on Wong (1999).

What Happened to Innovation in Late-industrialising Economies from the 1990s to the mid-2010s – Globalisation and the Second Unbundling

Baldwin (2016) described how the current late-industrialising economies, many of which are AMS, have succeeded in innovation by using the concept of 'unbundling' in the context of globalisation. According to Baldwin (2016), we experienced two waves of globalisation and have been in the third wave of globalisation. The first one began in the 1820s and continued to the 1980s, characterised by significant decreases in the cost of moving goods and unbundling the combination of production and consumption. The advent of steam, diesel, gas, and electric engines significantly decreased the cost of moving goods via land and sea transportation. Before the significant decrease in transportation costs, producing and consuming goods happened at a close distance. The continuous fall in transportation costs unbundled this combination and enabled firms in one country to sell their goods in a faraway country. This 'first unbundling' globalisation provides global markets for final goods and raw materials, but for very limited intermediate parts.

The second wave of globalisation started in the 1990s and carried on to the mid-2010s, characterised by decreases in the cost of moving ideas and unbundling factories or production stages. Before the second unbundling, high communication costs prevented firms in a given country from fragmenting their production processes across other countries even if they were low-wage countries. High communication costs provided relative efficiency of industrial agglomeration, or production units gathering spatially. This agglomeration induced innovation, followed by intensified industrial competitiveness and increases in exports. That industrial competitiveness promoted agglomeration. This virtuous cycle worked well in countries that industrialised early, or G7 countries. However, the information and communication technology (ICT) revolution in the 1990s stopped this virtuous circle. The improvement in ICT significantly reduced communication costs and enabled firms in developed countries to manage and control production units in far-flung low-wage countries (e.g. efficient supply chain management). Competitive firms in developed countries moved or established production units in low-wage countries. Typically, firms went from Germany to Central and Eastern Europe, from the United States to South and Central America, and from Japan to East and Southeast Asia. Accordingly, many AMS took advantage of the second unbundling through technology transfers (innovation) from developed countries. In other words, AMS late-industrialising economies have grown by participating in international production networks – the task-wise international division of labour (Kimura, 2020) – through the comparative advantages of lower costs of labour and by accumulating a stock of advanced production technologies.

Countries that developed their economies to a high-income level before 1990 – such as the Republic of Korea (henceforth, Korea), Hong Kong, Taiwan, and Singapore – are different from other late-industrialising economies in terms of the growth path. These East Asian high-income countries built their industrial competitiveness during the first unbundling. Although they started their development with low-income advantages, they established sufficient industrial competitiveness to compete with industries in advanced economies by building agglomeration and innovation capability. For example, Korea's automobile industry entered a low-price market segment based on its low labour cost advantage. After that, the firms invested intensively in imitative R&D (Wong, 1999) and built automobile industry agglomeration in the country (Baldwin, 2016). Further, automobile firms shifted their market positions towards leading-edge segments, and some finally overtook existing leading firms by surpassing their level of R&D investment to build product and process innovation capabilities (Wong, 1999). These East Asian high-income countries are in a position, like the G7 countries, to transfer their advanced technologies to other middle-income late-industrialising countries.

Latecomers in late-industrialising economies have been able to enjoy economic growth without competing with leaders in advanced economies. As seen in the latecomer advantages and disadvantages discussion above, latecomers must endeavour not to compete directly with leading firms in advanced economies before the second unbundling. As was the case with Korea's automobile industry, latecomers have to find a market segment in which they can run their businesses without competing directly with leading firms. Meanwhile, during the second unbundling, firms in late-industrialising markets did not have to do the same things as firms did previously. Significant decreases in the cost of moving ideas allow firms in both advanced economies and late-industrialising economies to build a win–win relationship, where the former provide production technologies and the latter provide low labour costs.

Impacts of Digital Transformation on Advantages and Disadvantages in Innovation for Latecomers and Late-industrialising Economies – Future Globalisation and the Third Unbundling

Baldwin's unbundling concept asserts that we are at the beginning of the third wave of globalisation, characterised by a decrease in the cost of the movement of people. This does not mean that people move physically across borders, but that the technology of telepresence enables people to communicate as if they were present in one place. Further, telerobotics allow people in one country to inspect or repair machinery in a factory located in another country. Currently, the costs of telepresence and telerobotics are high, but they will start decreasing soon. This decrease in face-to-face costs will unbundle individual tasks performed by a group of people in a fixed location into subdivided work performed by individual people in different locations , and will bring about a people-wise international division of labour (Kimura, 2018) or the third unbundling. In this unbundled world, people's human capital is digitalised and moves easily across borders, which Baldwin calls 'virtual immigration' or 'international telecommuting'. In this digitally connected world, distance is almost nothing. We have already experienced this to some extent because of the use of telework as a social distancing measure during the coronavirus disease (COVID-19) pandemic. This teleworking experience worldwide will not change our work styles entirely, but has changed people's minds about the necessity of face-to-face communication. The experience of the COVID-19 pandemic will encourage us to move forward towards the third unbundling.

Will the digitalisation trend and the person-wise international division of labour change late-industrialising economies' advantages and disadvantages in terms of the innovation capabilities described above? Generic advantages will not change because the discussion does not depend on digitalisation or the international division of labour. What about the advantages specific to late-industrialising economies? These advantages do not appear to change, and some of them may even be intensified. Various kinds of labour in late-industrialising markets may be embedded in global value chains. At least until late-industrialising economies catch up in terms of wage levels, the cost of labour remains lower than in advanced economies. Accordingly, decreases in the cost of (virtually) moving people may strengthen the competitiveness of indigenous firms, including self-employed people, in terms of labour costs. Regarding the sheltered local market advantages, local firms are likely to retain their advantageous position at least until local markets are significantly digitally transformed. Regarding the e-commerce market in the Association of Southeast Asian Nations (ASEAN) region, for example, Chen and Ruddy (2020) pointed out that the region's internet infrastructure seems to be at a satisfactory level compared with the world average, but the internet infrastructure levels are uneven between more developed countries and less developed countries as well as between urban and rural areas. A less digitalised market makes the market less accessible for firms located far from it. Accordingly, local firms can enjoy the advantage of being first movers and can grow their business in local markets. Moreover, for the same reason, the advantage of amplified information asymmetry seems to remain.

Next, what about late-industrialising economies' disadvantages? The generic disadvantages will not be changed by digital transformation in general. However, digital transformation will intensify winner-takes-all advantages. This is evident, as famous giant digital platforms (e.g. Apple, Google, Facebook, and Amazon) are typical businesses enjoying winner-takes-all advantages. Further, Chinese platforms (e.g. Alibaba) that have been fostered in a sheltered large-scale market are now extending their businesses globally, including in the ASEAN region. Digital transformation will mitigate the disadvantages specific to late-industrialising markets. Advanced economies have a more sophisticated level of digitalisation in terms of ICT infrastructure, data security, etc. than many ASEAN Member States. This means that the disadvantages of distance from lead users and distance from advanced technology sources will no longer be problems. People or firms located in the ASEAN region can now easily access the advanced economy advantages. Of course, they need to be located in a relatively developed area in terms of ICT. Although these areas may be limited at present, digital transformation has a significant positive impact on the ASEAN region in terms of reducing late-industrialising economies' specific advantages.

Overall, the third unbundling or digital transformation provides both positives and negatives to late-industrialising economies in terms of innovation capabilities. For people and firms in late-industrialising economies, digital transformation will intensify the advantages of lower labour costs and sheltered markets. Further, it will mitigate the disadvantages of accessing advanced technology and knowledge. Meanwhile, although it is not limited to late-industrialising economies, the current first movers of advanced economies (typically US internet platforms) are more likely than ever to enjoy first mover advantages in the winner-takes-all digital economy.

* If the change in taste occurs amongst all consumers at once, first movers will quickly abandon their existing assets since these assets become useless after the change. However, if the taste changes start in a particular section of consumers, the decision to abandon the assets is difficult for first movers.
** The concept of 'lead users' was originated by von Hippel (1986).

Source: Authors.

Box 2 Robots and AI – A New Economic Era

Over the past 3 centuries, we have witnessed various technological advances that have revolutionised production methods, business organisation, and the way people work and live. More recently, we have seen remarkable advances in the availability and uses of industrial robots and artificial intelligence (AI).

Starting from the invention of industrial robots in the late 1950s, they were traded in Europe by the 1960s, in Japan and the Republic of Korea by the 1970s, and internationally afterwards. As the technology developed, faster and more sophisticated robots began to be used for a range of manufacturing processes. Likewise, the most advanced technology invention – AI – is used to describe computations that mimic human cognitive functions such as learning or problem solving. AI has improved massively in the last decade, primarily due to the invention of machine learning techniques that enable computers to have superior predictive power at substantially reduced costs.

Industrial robots, especially those that apply AI, offer perhaps the greatest scope for technological improvement and productivity gains in the modern industrial era. The potential for robots and AI to improve the quality of life is enormous. At the same time, new technologies almost always carry unintended consequences. Industrial robots, run by AI, are bound to take over a range of tasks in production and thereby displace workers in the labour market. Workers who perform tasks that can be done more efficiently by robots may see a fall in wages and a need to change jobs. Moreover, industrial robots and AI will tend to widen income inequality.

Early research on the benefits of industrial robots and AI has emphasised two potential sources of gain. First, these technological advances reduce production and operational costs. Robots can perform many tasks faster than humans and with greater precision and accuracy. AI can be used to predict problems along the production line and to leverage computation as an input to production. Second, and perhaps less obvious, industrial robots and AI can help markets to function more efficiently. Industrial robots and AI can facilitate not only trade in goods, but also trade in services.

Source: Ing and Grossman (forthcoming)

References

Abramovitz, M. (1956), 'Resource and Output Trends in the United States Since 1870', *Occasional Paper*, No. 52. Cambridge, MA: National Bureau of Economic Research.

Acemoglu, D. (2009), *Introduction to Modern Economic Growth*. Princeton, NJ: Princeton University Press.

Aghion, P., J. Cai, M. Dewatripont, L. Du, A. Harrison, and P. Legros (2015), 'Industrial Policy and Competition', *American Economic Journal: Macroeconomics,* 7(4), pp.1–32.

Ambashi, M. (2018), 'Conclusion and Policy Recommendations', in M. Ambashi (ed.) *Innovation Policy in ASEAN*. Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA), pp.321–30.

Andrews, D., C. Criscuolo, and P.N. Gal (2015), 'Frontier Firms, Technology Diffusion and Public Policy: Micro Evidence from OECD Countries', *The Future of Productivity: Main Background Papers*. Paris: Organisation for Economic Co-operation and Development (OECD).

Andrews, D., G. Nicoletti, and C. Timiliotis (2018), 'Digital Technology Diffusion: A Matter of Capabilities, Incentives or Both?', *OECD Economics Department Working Papers*, No. 1476. Paris: Organisation for Economic Co-operation and Development (OECD).

van Ark, B., M. O'Mahoney, and M.P. Timmer (2008), 'The Productivity Gap Between Europe and the United States: Trends and Causes,' *Journal of Economic Perspectives*, 22(1), pp.25–44.

Baldwin, R. (2016), *The Great Convergence: Information Technology and the New Globalization*. Cambridge, MA: Belknap Press of Harvard University Press.

Bartelsman, E.J. and P.J. Dhrymes (1998), 'Productivity Dynamics: US Manufacturing Plants, 1972–1986', *Journal of Productivity Analysis,* 9, pp.5–34.

Bloom, N., R. Sadun, and J. Van Reenen (2012), 'Americans Do IT Better: US Multinationals and the Productivity Miracle', *American Economic Review,* 102(1), pp.167–201.

Bresnahan, T.F. and M. Trajtenberg (1995), 'General Purpose Technologies "Engines of Growth"?' *Journal of Econometrics*, 65(1), pp.83–108.

Chen, L. and L. Ruddy (2020), 'Improving Digital Connectivity: Policy Priority for ASEAN Digital Transformation', *Policy Brief*, No. 2020-07. Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA).

Cherif, R. and F. Hasanov (2019), 'Principles of True Industrial Policy', *Journal of Globalization and Development*, 10(1), 20190034.

Foster, L., J.C. Haltiwanger, and C.J. Krizan (2001), 'Aggregate Productivity Growth: Lessons from Microeconomic Evidence', in C.R. Hulten, E.R. Dean, M.J. Harper (eds.) *New Developments in Productivity Analysis*. Chicago: University of Chicago Press, pp.303–72.

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

Fukugawa, N. (2018), 'Division of Labor between Innovation Intermediaries for SMEs: Productivity Effects of Interfirm Organizations in Japan', *Journal of Small Business Management*, 56(S1), pp. 297–322.

Griffith, R., S. Redding, and J. Van Reenen (2004), 'Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries', *Review of Economics and Statistics*, 86(4), pp.883–95.

von Hippel, E. (1986), 'Lead Users: A Source of Novel Product Concepts', *Management Science*, 32(7), pp.791–805.

Ho, Y.-P., P.-C. Low, and P.-K. Wong (2014), 'Do University Entrepreneurship Programs Influence Students' Entrepreneurial Behavior? An Empirical Analysis of University Students in Singapore', *Innovative Pathways for University Entrepreneurship in the 21st Century*, Advances in the Study of Entrepreneurship, Innovation and Economic Growth, Volume 24. Bingley, UK: Emerald Group Publishing Limited, pp.65–87.

Iacovone, L. and G.A. Crespi (2010), 'Catching Up with the Technological Frontier: Micro-level Evidence on Growth and Convergence', Industrial and Corporate Change, 19(6), pp.2073–96.

Ing, L.Y. and G.M. Grossman, eds. (forthcoming), *Robots and AI: A New Economic Era*. New York and Oxon: Routledge.

Inoue, H. and E. Yamaguchi (2017), 'Evaluation of the Small Business Innovation Research Program in Japan', *SAGE Open,* January–March, pp.1–9.

Jones, C.I. (2016), 'The Facts of Economic Growth', in J.B. Taylor and H. Uhlig (eds.) *Handbook of Macroeconomics*, Volume 2A. Amsterdam: North-Holland (Elsevier), pp.3–69.

Kimura, F. (2018), '"Unbundlings" and Development Strategies in ASEAN: Old Issues and New Challenges', *ERIA Discussion Paper Series,* ERIA-DP-2017-14. Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA).

Kimura, F. (2020), 'Exit Strategies for ASEAN Member States: Keeping Production Networks Alive Despite the Impending Demand Shock', *Policy Brief,* No. 2020-03. Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA).

Kimura, F., R. Shrestha, and D. Narjoko (2019), 'The Digital and Fourth Industrial Revolution and ASEAN Economic Transformation', in F. Kimura, V. Anbumozhi, and H. Nishimura. (eds.) *Transforming and Deepening the ASEAN Community.* Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA), pp.1–23.

Kimura, F., P.K. Wong, and M. Ambashi (2019), 'Innovation for ASEAN 2040', in F. Kimura, V. Anbumozhi, and H. Nishimura. (eds.) *Transforming and Deepening the ASEAN Community*, Jakarta: Economic Research Institute for ASEAN and East Asia (ERIA), pp.24–49.

Kretschmer, T. (2012), 'Information and Communication Technologies and Productivity Growth: A Survey of the Literature', *OECD Digital Economy Papers,* No. 195, Paris: Organisation for Economic Co-operation and Development (OECD).

Krugman, P.R. (1997), *The Age of Diminished Expectations: US Economic Policy in the 1990s*. Cambridge, MA: MIT Press.

Lerner, J. (1999), 'The Government as Venture Capitalist: The Long-Run Impact of the SBIR Program', *The Journal of Business*, 72(3), pp.285–318.

OECD (2021), *Promoting the Productivity of SMEs in ASEAN Countries – Strengthening Capabilities, Enabling Business Dynamics*. Paris: Organisation for Economic Co-operation and Development (OECD).

OECD/Eurostat (2018), *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition, The Measurement of Scientific, Technological and Innovation Activities*. Paris and Luxembourg: Organisation for Economic Co-operation and Development (OECD) and Eurostat.

Martens, B. (2020), 'An Economic Perspective on Data and Platform Market Power', *JRC Digital Economy Working Paper*, No. 2020-09. Brussels: European Commission Joint Research Centre.

Porter, M.E. (1990), *The Competitive Advantage of Nations.* New York: The Free Press.

Rysman, M. (2009), 'The Economics of Two-Sided Markets', *Journal of Economic Perspectives*, 23(3), pp.125–43.

Sauermann, H. (2018), 'Fire in the Belly? Employee Motives and Innovative Performance in Start-Ups Versus Established Firms', *Strategic Entrepreneurship Journal,* 12(4), pp.423–54.

SBIR (n.d.), Small Business Innovation Research. https://www.sbir.gov/ (accessed 26 October 2021).

Siegel, D.S. and C. Wessner (2012), 'Universities and the Success of Entrepreneurial Ventures: Evidence from the Small Business Innovation Research Program', *Journal of Technology Transfer,* 37(4), pp.404–15.

Soete, L., B. Verspagen, and B. ter Weel (2010), 'Systems of Innovation', in B.H. Hall and N. Rosenberg (eds.) *Handbook of The Economics of Innovation*, Volume 2. Amsterdam: Elsevier, pp.1160–79.

Solow, R.M. (1956), 'A Contribution to the Theory of Economic Growth', *The Quarterly Journal of Economics*, 70(1), pp.65–94.

Startup SG (n.d.), https://www.startupsg.gov.sg/ (accessed 26 October 2021).

Swan, T.W. (1956), 'Economic Growth and Capital Accumulation', *Economic Record,* 32(2), pp.334–61.

Ueki, Y. (2020), 'Production Networks and Technology Transfer: –Empirical Analysis Based on Survey Data for Companies in Southeast Asia–', *Public Policy Review*, 16(1), pp.95–120.

University of Groningen, Groningen Growth and Development Centre (n.d.), Penn World Table version 10.0. https://www.rug.nl/ggdc/productivity/pwt/ (accessed 20 June 2021).

Ventura, J. (1997), 'Growth and Interdependence', *The Quarterly Journal of Economics,* 112(1), pp.57–84.

Wong, P.K. (1999), 'National Innovation Systems for Rapid Technological Catch-Up: An Analytical Framework and a Comparative Analysis of Korea, Taiwan and Singapore', Paper Presented at the DRUID Summer Conference on National Innovation Systems, Industrial Dynamics and Innovation Policy, Rebild, Denmark, 9–12 June.

Wong, P.K. (2014a), 'Catching Up or Breaking Out? Capability Development Strategy of Latecomer Firms and Nations', Presentation at the Technology and Management Centre for Development Seminar, Oxford Department of International Development, University of Oxford, 13 March. https://www.oxfordtmcd.org/sites/default/files/attachments/Oxford%20TMCD%20Seminar.pdf

Wong, P.K. (2014b), 'Innovation and Inclusive Growth in Emerging Economies', Presentation at the Symposium on Innovation and Inclusive Growth, OECD, Paris, 20–21 March. https://www.oecd.org/sti/inno/Session_1_Poh%20Kam%20Wong.pdf

World Bank (n.d.), World Bank Country and Lending Groups. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups (accessed 8 August 2021).