ASIA’S JOURNEY TO PROSPERITY
Policy, Market, and Technology over 50 Years

Chapter 5: Technological Progress as Key Driver
Outline

01 Overview of Asia’s technological development
02 Measuring technology’s contribution to growth
03 Asia’s technological progress: products, patents, robots
04 Modalities of technological progress
05 Country experiences on technology policies
06 Recent technological trends and development
07 Looking ahead
08 Questions and further readings
1. Overview of Asia’s technological development

• Asia’s growth and development over the past 50 years was built on significant advances in technology. Technological development helps to improve productivity and raise living standards.

Asia pioneered the use of high-speed trains and currently operates three-quarters of the global high-speed rail network.

Asia currently manufactures more than 50% of the world’s automobiles, produces 75% of its robots, and provides 50% of global high-technology exports.

• Asia’s technological progress over the past 50 years has been significant. Compared with the 1960s, the range and quality of goods and services produced has grown phenomenally.
1. Overview of Asia’s technological development (cont.)

- Historically, Asia invented a variety of technologies that predate its interaction with the West. The People’s Republic of China (PRC) invented: papermaking, movable-type printing, gunpowder, and the compass.

- But starting from the Renaissance and then the Industrial Revolution, Asia fell behind the West in science and technology.

- Asia started to catch up again after World War II.
2. Measuring technology’s contribution to growth

- One measure of technology’s contribution to growth is the so-called “total factor productivity” or TFP.

- Using an aggregate production function, gross domestic product (GDP) is based on four inputs:
  - Capital
  - Labor
  - Human Capital
  - TFP

TFP captures:
- advances in product and process technologies
- efficiencies from managerial, institutional, and policy reforms.
- other contributions to GDP, such as quality of education and training
2. Measuring technology’s contribution to growth (cont.)

- TFP can be estimated through a “growth accounting framework.”

The Cobb–Douglas form of the production function, assumes constant returns to scale in capital (K), labor (L), and human capital (H) and diminishing marginal productivity of K, L, and H.

\[
(1) \quad Y = A K^a L^b H^{1-a-b} \quad \text{where } 0 < a < 1, \ 0 < b < 1, \ \text{and } a+b < 1.
\]

Using total differentiation, one can derive a “growth accounting” formula, which explains GDP growth based on the growth of technology (A), capital, labor, and human capital:

\[
(2) \quad \frac{\Delta Y}{Y} = \frac{\Delta A}{A} + a \frac{\Delta K}{K} + b \frac{\Delta L}{L} + (1-a-b) \frac{\Delta H}{H}
\]

where \(\Delta\) denotes the change in a variable. With this equation, the rate of technological progress (\(\Delta A/A\)) can be computed as a “residual”:

\[
(3) \quad \frac{\Delta A}{A} = \frac{\Delta Y}{Y} - a \frac{\Delta K}{K} - b \frac{\Delta L}{L} - (1-a-b) \frac{\Delta H}{H}
\]
Using the growth accounting framework, we observe that over the past half century, growth in Asia has relied increasingly on TFP growth.

- From 1970 to 1985, capital and labor drove growth. This was also a period of economic turbulence, leading to negative TFP growth.
- From 1995 to 2005, TFP growth makes a positive contribution to growth.
- From 2010-2017, TFP growth contribution increased further to 40%.

### Contribution of Factors of Production to GDP Growth, Asia (% of total contribution)

<table>
<thead>
<tr>
<th>Year</th>
<th>Capital input</th>
<th>Labor input</th>
<th>Human capital</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970-1985</td>
<td>15.0</td>
<td>31.2</td>
<td>60.4</td>
<td>(6.6)</td>
</tr>
<tr>
<td>1995-2005</td>
<td>21.9</td>
<td>12.3</td>
<td>17.7</td>
<td>48.2</td>
</tr>
<tr>
<td>2010-2017</td>
<td>40.8</td>
<td>9.7</td>
<td>8.1</td>
<td>41.8</td>
</tr>
</tbody>
</table>

( ) = negative, GDP = gross domestic product, TFP = total factor productivity.

Notes: Central Asia is excluded for 1970–1985.

Significant technological improvement and greater efficiency may be needed for countries to progress from a middle- to high-income level.

The contribution of TFP growth was 28% for economies that reached high-income level from initial middle-income status, whereas the contribution was just under 10% for economies that remained middle-income.

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Notes: The calculations include both Asian and non-Asian economies and are the sum of a decade-by-decade analysis. Those that stayed middle income did so through the decade, while those that moved to higher income started the decade at middle income and moved to high income by the end of the decade. The number of economies included varies by decade. For the “staying at middle income” group, about 40 economies were used for each decade. For the “moving from middle income to high income” group, the number ranges from 14 in the 1970s to four in the 1980s.

Three proxy measures to capture the evolution of technology in the region:

1. Complexity of a country’s exports
2. Number of patents awarded
3. Number of robots manufactured and sold for use in production
Asia’s technological progress can be seen in the goods it produces and those that it exports.

- In the 1960s, much of Asia’s production and exports were in agricultural and primary commodities, as well as light manufacturing products.

- The region has since produced more sophisticated goods.
  - For example, some 56% of automobile production worldwide takes place in Asia recently.
  - Currently, the top two smartphone companies globally, by sales, are based in the PRC and the Republic of Korea (ROK), and Asian firms account for eight of the top 10.
3. Asia’s technological progress – Product sophistication (cont.)

- A way to measure the sophistication of countries’ production capabilities is through plotting their product complexity index. It shows that high-income economies have a larger share of more complex goods in their export basket.

The Flying Geese Pattern of Asian Exports  
(average for 2013-2017)

- Japan has a high share of the most complex goods
- The PRC exports large quantities of mid-tech products (electronics and electronic goods)

Notes: Data are for manufactured exports on a value-added basis, averaged for 2013–2017. Input–output data are used to calculate value added. The y axis depicts each economy’s exports of a product group as a share of total Asian exports of all product groups. Total Asian exports is based on 24 economies. The x axis represents the following product groups, arranged by increasing complexity: (i) leather and footwear; (ii) textiles and textile products; (iii) manufacturing not elsewhere classified (nec) and recycling; (iv) wood and products of wood and cork; (v) other nonmetallic minerals; (vi) basic metal and fabricated metal; (vii) food, beverages and tobacco; (viii) rubber and plastics; (ix) electrical and optical equipment; (x) pulp, paper, printing, and publishing; (xi) chemicals and chemical products; (xii) machinery, nec; and (xiii) transport equipment.

• The graph also shows that middle-income economies have a larger share of mid-complexity goods.

The Flying Geese Pattern of Asian Exports
(average for 2013-2017)
Southeast Asia and Hong Kong, China

A spike occurs for food and beverages at the seventh vertical line, especially among middle-income economies.

The earlier graphs reinforce the "flying geese" model often used to signify the pattern of industrialization in the region, which generalizes dynamic patterns of industrial catch-up.

- According to the flying geese model, industries relocate from advanced to developing economies sequentially, starting in light industries requiring lower technology.

- But, at the same time, we can observe the emergence of intra-industry trade in addition to interindustry trade.

3. Asia’s technological progress – Product sophistication (cont.)
3. Asia’s technological progress – Product sophistication (cont.)

- The inter-economy and interindustry “flying geese” development model evolved over time into a more complex and dynamic structure of intra-industry regional and global value chains.

3. Asia’s technological progress – Number of patents

Over the past 5 decades, Asia transformed itself from primarily adopting technology from others to creating new technology.

Top 5 Patent Grantees in the United States

<table>
<thead>
<tr>
<th></th>
<th>1960s</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Germany</td>
<td>Japan</td>
</tr>
<tr>
<td>2</td>
<td>United Kingdom</td>
<td>Republic of Korea</td>
</tr>
<tr>
<td>3</td>
<td>France</td>
<td>Germany</td>
</tr>
<tr>
<td>4</td>
<td>Japan</td>
<td>Taipei, China</td>
</tr>
<tr>
<td>5</td>
<td>Canada</td>
<td>People’s Republic of China</td>
</tr>
</tbody>
</table>

In 1965–1969, only one of the top 10 foreign economies that were awarded patents in the United States (US) was from Asia (Japan), with all others from Europe and Canada. However, by 2015, there were four Asian economies among the top five.

Moreover, if each economy’s total patents granted (domestically and in other countries under the Patent Cooperation Treaty) is considered, the PRC ranked first in the world in 2018.

Asian companies and research institutions have been increasingly protecting their intellectual property in overseas markets, illustrating the region’s expanding globalization of its homegrown research and development (R&D) and business activities.

Notes: These refer to patents for inventions covering the creation of a new or improved—and useful—product, process, or machine. The origin of a patent is determined by the residence of the first-named inventor. Periods refer to years when patents were granted.
3. Asia’s technological progress – Robots

- Asia is the global leader in both producing and using robots.
  - Japan is the single largest manufacturer of robots. Japan, the PRC, and the ROK accounted for about 75% of all robots made globally in 2015.
  - The PRC is by far the largest user of new robots worldwide.
  - Among the top 15 purchasers worldwide are seven other Asian economies: Japan, the ROK, Taipei, China; Viet Nam; Singapore; India; and Thailand.


4. Modalities of technological progress

A country’s development is likely to undergo an initial phase of adoption-based technological progress and growth, and a later phase of own innovation-based growth.

**Modalities of adoption-based technological progress**
- Licensing
- Reverse engineering
- Machine imports
- Trade
- Foreign Direct Investment
- Technical cooperation aid

**Drivers of innovation-based growth**
- Research and development
- Upskilling of human capital
- Protection of intellectual property rights
- Market competition

In many countries, including advanced economies and Asian emerging economies, the process of adoption and innovation occur simultaneously.
4. Modalities of technological progress—licensing

• New technologies can be acquired by obtaining licenses for patents, industrial designs, and other intellectual property from abroad.

  ❖ Using licenses effectively requires human capability. Asia’s now high-income economies used licensing extensively during development and they, along with other economies, continue to do so.

    ○ For example, Taipei, China began its electrical and electronics sector in the late 1950s with licenses for key designs from Japan. It began by producing electrical meters and later used licensed technology for television production.

  ❖ Many companies in Taipei, China (e.g. Foxconn) began adopting the original equipment manufacturer (OEM) business model based on licensed technology. Later these companies (e.g. Acer and Asus) would develop their own designs, shifting from adoption to innovation.

  ❖ As an economy develops its own technology, it starts to sell technology licenses to firms abroad and becomes a licenser (exporter/seller of licenses) (e.g. Japan since 2003).
4. Modalities of technological progress – trade and foreign direct investment

- International trade has been an important driver of technological adoption and innovation.
  - Asia acquired technologies for efficient production of manufactured goods, initially by importing machines and instruments.
  - Exports can also contribute to technological progress because exporting firms can learn about foreign technologies through the export process, and about competing products in global markets.
  - Exports can also generate foreign exchange that can enable the purchase of licenses and machinery.
  - Trade incentivizes a country to promote R&D and skills development where it holds comparative advantage.

- Foreign direct investment (FDI) can be a key conduit for technology transfer, as multinational corporations (MNCs) carry with them the latest technologies as well as new business models and management know-how
  - Singapore offered an environment conducive for MNCs in manufacturing, finance, and logistics. Malaysia, Thailand, and the PRC built their manufacturing base on large amounts of FDI and used an active strategy that included special economic zones.
  - 1960s to 1980s: Many economies leveraged FDI to build local capacity of enterprises through the use of local content requirements.
  - Technology transfer through FDI may occur in unintended ways. An example is the Bangladesh garment sector. Employees from Desh, a local company received training from Daewoo, its joint venture partner.
4. Modalities of technological progress – technical cooperation aid and reverse engineering

• Technical cooperation aid can facilitate adoption of new technologies and raise an economy’s absorptive capacity.
  ❖ After World War II, the US sent experts to the region (e.g., the ROK; Taipei, China; Southeast Asia) and invited students and trainees to the US.
  ❖ Japan, Australia, and Europe, also played an important role in Asia through their aid programs.
  ❖ Technological cooperation was the second-largest contributor of technological transfer (after trade)

• Reverse engineering has been a common technique for acquiring technology. By disassembling a product, countries learned how the good was produced.

<table>
<thead>
<tr>
<th>Company</th>
<th>Reverse Engineered Products</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Toyota</td>
<td>US car in 1993</td>
<td>Toyota produced the first model A1 car in 1935.</td>
</tr>
<tr>
<td>2 LG Electronics</td>
<td>US and Japanese products</td>
<td>LG in 1985 produced the first transistor radios in the ROK.</td>
</tr>
<tr>
<td>3 Samsung</td>
<td>Semiconductors, RAM chips</td>
<td>Samsung became a leader in producing higher-capacity chips.</td>
</tr>
<tr>
<td>4 Acer</td>
<td>Minicomputers and microprocessors</td>
<td>Acer became a global brand of computer equipment.</td>
</tr>
</tbody>
</table>

RAM=random access memory; US=United States
4. Modalities of technological progress – R&D

- As economies develop and move closer to the global technological frontier, they focus more on indigenous innovation, facilitated by R&D.
  - In Asia, human resources and funding have been channeled into corporate laboratories and public research institutes.
  - Other middle-income economies in Asia have also recently increased spending on R&D to promote innovation.
  - The last half century saw the development of high-quality universities in Asia. Of the world’s top 100 in science and mathematics, 15 are from the region.

GDP = gross domestic product, PRC = People’s Republic of China.
4. Modalities of technological progress – industrial clusters and agglomeration

• Technological learning occurs when enterprises locate near each other in clusters and as part of industrial estates and technology parks. This proximity generates Marshallian or technological externalities.

❖ Many clusters develop naturally, based either on access to a key raw material or the establishment of one or more lead firms. Modern technology clusters are often located near universities and research institutes.

❖ Asia is home to a great variety of traditional clusters, such as large auto industry clusters in Tokyo (Japan) and Ulsan (the ROK); producers of footballs and surgical instruments in Sialkot, Pakistan; software and business process outsourcing (BPO) industry clusters in Bengaluru, India; and garment clusters in Bangladesh and Cambodia.

❖ Shenzhen in southern PRC is an urban and high-tech metropolis that is home to some of the country’s largest and more progressive companies. It was the first special economic zone established and is often called the PRC’s Silicon Valley.
International and domestic market competition has been a major force in promoting Asia’s technological progress. Where there is competition, firms maintain or increase their market position by adopting new processes and products.

- For market competition to facilitate innovation, proper policies are critical—including laws on fair competition, bankruptcy, consumer protection, and intellectual property.
- Research suggests an inverted U-shaped relationship between competition and innovation, with very low and very high levels of competition slowing technology development.
- Selecting capable companies can occur naturally through moderate competition, mergers and acquisitions, and the exit of inefficient enterprises.
4. Modalities of technological progress—structural transformation

- Asia’s experience also shows that technological progress is part of a process of structural transformation (shifts in production and employment) from agriculture to industry (especially manufacturing) and services.

- Technological developments in agriculture and manufacturing have been mutually reinforcing.

- As technology improvements in manufacturing generated productivity growth and employment opportunities, the resulting labor movement from agriculture to non-agriculture sectors raised agricultural wages, “inducing” the use of labor-saving technology.

5. Country experiences on technology policies

- Through supportive policies, Japan and the ROK have been leaders in technology adoption and innovation in Asia.

**Japan**
- Japan relied more on imported foreign technology through licensing and other modalities during the postwar recovery and catching-up process, and later increasingly moved on to innovation.

**ROK**
- The ROK grew from a poor country with low technological development in the early 1960s to a leading center of innovation in electronics, chemicals, automobiles, and other industries.
- This transformation relied on intensive use of technological adoption from abroad that over time became the basis for the shift to indigenous innovation.
- A key aspect of the country’s transition was active state intervention to promote development based on technology.

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*Adoption and Innovation of Technologies in Japan, 1956–1988 (%)*

- R&D/GNP (left scale)
- Net Technology Imports/GNP (right scale)

5. Country experiences on technology policies (cont.)

- More open policies, supporting technology transfer through trade and FDI, have also aided PRC and India’s technological upgrading.

**India**
- India started as a labor-intensive economy. Technological learning was limited.
- From the mid-1980s, it began to pursue a more open policy, a time when information technology (IT) was expanding worldwide.
- India’s top IT firms were established. Training of engineers and scientists had also been expanding.
- It established software technology parks and introduced other infrastructure and trade policy changes, inducing a massive flow of software outsourcing to India in the 1990s.
- IT-enabled services/BPO industry expanded.
- Today, India’s software and IT-enabled service industry supplies about 8% of India’s output and accounts for $137 billion in exports.

**PRC**
- The PRC relied on a variety of foreign sources for technological advancement, such as the former Soviet Union in the 1950s, and Japan and Western countries since the 1980s.
- Technology transfer through FDI and markets became a new focus from 1985 onward. The PRC initiated science and technology policy reforms and set up many foreign-domestic joint ventures.
- In 2006, it introduced “indigenous innovation” as a priority. A broader technology development plan was adopted in 2015 to increase domestic content in the high-technology sectors.
- The PRC has become a top R&D spender, with a workforce of about 4.2 million researchers in 2018. It launched “Made in China 2025” in 2015.
5. Country experiences on technology policies (cont.)

- Economies within and across subregions also exhibit a diversity of experiences and strategies for technological upgrading.

**Thailand**
- In the 1970s, Thailand began building a manufacturing sector based on FDI, which brought in the technology it needed. In the 1980s, the government began building public research infrastructure.
- In 2014, the government unveiled Thailand 4.0, a vision to lead the country into the 4th Industrial Revolution (IR). The strategy is closely tied to the Eastern Economic Corridor.

**Kazakhstan**
- From the early 2000s, Kazakhstan introduced policies and programs to develop a national system of technology and innovation.
- Public financing was added in 2003 to promote development of high-tech and knowledge-based industries.
- In 2006, a major infrastructure initiative began with the establishment of a special economic zone information technology park.
- The country’s innovative ecosystem includes an independent cluster fund, industrial zones, technoparks, technology commercialization centers, international centers of technology transfer, and venture capital funds.

**Malaysia**
- Malaysia has focused attention on science and technology in economic planning since 1986. In 1991, it established a framework for a future knowledge-based economy. In recent years, Malaysia introduced fiscal and non-fiscal measures to promote research and innovative activities by foreign and domestic firms.
6. Recent technology trends and development

• Various new technologies have emerged more recently, both globally and in the region. A large part of these innovations occurs in services.

❖ A few examples of the new technologies include:

1. Information and communication technology (ICT) - enabled BPO
2. Online payments
3. E-commerce
4. Artificial intelligence
5. New logistics technologies using drones and satellite-based technology
6. Social media
7. And shared economies such as Airbnb and Uber.

❖ Platform companies are changing the way of life.
6. Recent technology trends and development (cont.)

- The speed of global technological innovation appears to be accelerating.

![Diffusion Speed of Technologies](image)

- It took about 45 years for the penetration rate of landline telephones in the US to rise from 5% to 50%, while it took only 9 years for the entire world to reach the same rate for mobile phones.

Note: Mobile phone is based on subscriptions; a person may have more than one.

Sources:
6. Recent technology trends and development (cont.)

• This current technological change is driven by the 4th Industrial Revolution, which builds on the ICT revolution and is fueled by the convergence of digital, physical, and biological innovation.

  ❖ More sophisticated robots and computing capacity, artificial intelligence, and machine learning underpin these changes. New advances in nanotechnology, materials, and biogenetics are also affecting the process.

  ❖ Beyond the factory, the 4th IR has transformed the link between producers and consumers, in how demand is assessed, how demand is made, and how goods and services are delivered.
6. Recent technology trends and development (cont.)

• Some Asian countries are already leading innovation in several areas. The region is also home to many creative, practical, and indigenous innovations that improve everyday lives.

  ❖ Japan leads in robotics, ROK in semiconductors, and the PRC in 5G cellular networks, e-commerce, and artificial intelligence. India and the Philippines leveraged the ICT revolution.

• Asian technological development based on the “flying geese” model has been changing. Countries now have a chance to leapfrog from lower stages of technological development to the frontier.

  ❖ Technologies connect countries via trade, FDI, global value chains, and the mobility of people. The core challenge for developing Asia is to keep up with the accelerated speed of global technological progress and take advantage of the opportunities provided.
7. Looking ahead

• To continue innovating and adopting new technologies to achieve sustainable and inclusive growth, policy makers in the region can focus on:
  ❖ Developing a diverse cadre of educated and skilled people in science and technology.
  ❖ Investing in and managing the expansion of digital infrastructure.
  ❖ Continuing to promote R&D.
  ❖ Fostering good institutions for innovation.
  ❖ Responding to the impact of new technologies on jobs, inequality, privacy, and other social consequences such as data-driven discrimination and crimes.

• Regarding the impact on jobs, there are several reasons for optimism.
  ❖ First, new technologies often automate specific tasks, not an entire job.
  ❖ Second, automation proceeds only where it is both technically and economically feasible.
  ❖ Third, rising demand offsets job displacement driven by automation.
  ❖ Fourth, technological change and economic growth create new occupations and industries, including green jobs.

• Some challenges remain (e.g. new skill requirements needed for new technologies; vulnerability of less-skilled workers, etc.).
  ❖ Governments can respond to these challenges by ensuring workers are protected from the downside of new technologies and are able to harness the new opportunities they provide.
8. Questions and further readings

- **Questions**

  01. What are the conceptual links between technology and growth?

  02. Why didn’t the industrial revolution happen in Asia? What have been the key achievements and drivers of Asia’s technological progress in the past 50 years?

  03. How can the contribution of technology be measured? What are its proxy measures?

  04. What are the modalities and examples of adoption-based technological progress in Asia? Those for innovation-based technological progress?

  05. How do market competition, trade, and FDI bring about technological progress? Describe the evolution of product sophistication in Asia in terms of the flying geese model and GVC model.

  06. What are challenges and opportunities stemming from the probable impact of automation on jobs? What should the role of government be to address these challenges and capture opportunities?
Further readings

8. Questions and further readings (cont.)

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• Further readings
Thank you!

The soft copy of the book can be downloaded at

https://www.adb.org/publications/asias-journey-to-prosperity