Networking for Technology Acquisition and Transfer

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* The views expressed in this paper are those of the author and do not necessarily reflect the views of the Secretariat of the United Nations Industrial Development Organization (UNIDO). The document has not been edited.
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Summary

The importance of technology is widely recognized. World Development Report 1991 states that productivity growth, the best proxy for technology progress, accounted for as much as 30 percent of GDP growth in the East Asian countries. Thus, technology is the engine of growth.

This technology changes the paradigm of economic activities and networking. Because of the advancement of technologies of information, communication and transportation, technology fusion, the acceleration of technological innovation and science orientation, market competition becomes wider and harder despite easier market entry and networking becomes more international, inter-sectoral and inter-institutional.

Technology also changes the mode of technology transfer and technology strategy. Any entity can easily access to available technology worldwide; and technology transfer becomes easier and more formal since some portion of tacit knowledge is codified and stored using information technology and microelectronics technology. For technology strategy, national strategy places more emphasis on private sector initiative; and corporate strategy becomes more comprehensive including the functions from procurement to marketing and network-oriented.

Technology acquisition from overseas is important especially for developing countries. The means of technology acquisition from overseas ranges from foreign direct investment (FDI), the most comprehensive one, to licensing. A suitable means depends on the condition of a recipient country. To facilitate technology acquisition from overseas, various policy efforts are required from macro economic policy to education policy.

Though technology acquisition from overseas is important, it is only one part of technology development. Technology assimilation and domestic diffusion is necessary for full use of acquired technology. It is not easy to assimilate foreign technology. Based on these experiences, a company or a country develops its own technology.

To utilize all technological capability for industrial development, collaboration among industry, universities and public research institutes is necessary. This necessity is stronger these days because technology has become more science-based and the size of corporate laboratories is shrinking. However, changing the culture of universities and public research institutes and their systems is never easy.

Finally, the paper points out that networking is indispensable and that domestic efforts and conditions determine the country performance of networking.

1 This paper is largely based on Kondo (1998).
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1. Technology as the Engine of Growth

Importance of technology for development is widely recognized. In industrialized economies, many studies have shown that more than 50 percent of long-term economic growth stems from technological changes that improve productivity and lead to new products, processes or industries.\(^2\) In the East Asian countries, productivity growth, the best proxy for technology progress, accounted for as much as 30 percent of gross domestic product (GDP) growth.\(^3\)

Technology progress is the key to international competitiveness and economic growth. Of four inputs to production--capital equipment, raw materials, labor and technology--, technology is the only one that is not physically limited. Though it seems that employing a large quantity of capital equipment increases productivity, it is not necessarily so.

The importance of technology is seen when considering a production function. This function omits raw material as an input and takes value added as an output. Technology is the only source of output increase without increasing capital or labor as inputs. Wealth is increased by technology.

\[
\frac{dY}{Y} = \frac{dT}{T} + a \frac{dK}{K} + b \frac{dL}{L}
\]

- \(dT\): total factor productivity increase (technology progress)
- \(dY\): output (value added) increase
- \(dK\): capital increase
- \(dL\): labor increase
- \(a, b\): coefficients where \(a + b = 1\).

Technology is also important to think of labor productivity as follows.

\[
\frac{dy}{y} = \frac{dT}{T} + a \frac{dk}{k}
\]

where \(y = Y/L\) and \(k = K/L\).

Thus, a labor productivity increase rate is determined by a technology progress rate and an increase rate of a capital per labor ratio. As far as capital investment in the form of foreign direct investment (FDI) and others continues, labor productivity increases. However, it will not last long as Paul Krugman warned the East Asian Miracle in his paper\(^4\).

Technology development is also vitally important for the world from environment consideration. Technology development saves energy and resources through productivity improvement and quality improvement. This will lead to the reduction of green house effect gases and will realize sustainable development. Productivity improvement directly reduces energy and materials used to produce the same amount of products. Quality improvement reduces energy and materials by reducing the number of defects and readjustment in the production process. Quality improvement reduces losses after shipment as well by avoiding the transport of defect products, the check of products at the next customer and the assembling of products containing defect components.

Good news for a country under industrial development is that it has a great potential to make technology progress. Technology progress is rapid at the early stages of economic development.

\(^2\) See Kim (1997).
\(^3\) See The World Bank (1991), page 88.
\(^4\) See Krugman (1994).
development. In Japan, a technology progress rate, or a total factor productivity growth rate, was high in the early 1960s when Japan was developing and became lower to one seventh of that in the late 1970s and early 1980s as its economy matured (Figure 1). This fact implies that technology strategy needs to be modified according to the stage of development.

2. Paradigm Shifts Caused by Technology

2.1 Economic Activities and Networking

Technology development has, on one hand, changed the mode of market competition. Because of the development of information technology, communication technology and transportation technology, we now live in a borderless economy and face global competition (Figure 2).

The mode of technology development has, on the other hand, changed. Technology fusion, such as mechatronics, is occurring. An industry sector needs to work with another industry sector. A competitor may appear from unpredictable industry sectors. This change fosters inter-industry or sectorless competition and collaboration.

The speed of technology development has been accelerated and life cycles of products have become shorter. One company alone cannot afford to conduct R&D (research and development) in various fields speedily. Companies need to find collaborators because of R&D resource limitation.

Technology itself changes as everything changes except changes. Technology has become more science-based especially in high-tech areas. This change compels companies to work with universities and public research institutes.

Thus, technology has changed the paradigm of economic activities. At the economy level, borderless economy appears; at the industry level, sectorless competition and collaboration appear; and at the firm level, corporate boundaryless business appears.

Networking is functioning accordingly. At the economy level, international networking in the area of R&D takes place vigorously (Figure 3). Except the United States, companies in many countries ally with foreign companies. At the industry level, companies in different industry sectors and researchers in different technology fields collaborate in R&D. At the firm level, companies cooperate with other companies and with universities and public research institutes. Real business takes place in the domain where multiple players work together.

In Japan, a special policy was formulated to facilitate networking among small-and-medium-size enterprises (SMEs) in different industry sectors. This policy is called “Igyoshu Koryu Plaza (Inter-sector Exchange Plaza)” and has been successful (See Box 1).

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6 Technology strategy changes as a country develops. See Kim and Dahlman (1992) and Chapter 5 of Kondo (1998).
7 See DTI (2000).
8 See Kodama (1991) for inter-industry competition and technology fusion.
2.2 Technology Transfer

Technology transfer is largely influenced by the technology development and changes of technology described above. Access to the information of technologies has become much easier thanks to the development of information technology and communication technology worldwide. However, the situation is the same for anyone. We need to learn how to find right information quickly.

Technology is defined as follows. Technology is knowledge necessary to design and/or produce a product or a set of service retained by an individual or an organization. It can be embodied in machinery and other products or service. This knowledge, resulting from accumulating experiences in R&D, design, production and capital investment, is mostly tacit, that is, not made explicit in any collection of blueprints and manuals. Only a part of that knowledge is codified in manuals and blueprints.

Whether knowledge is codified or tacit relates to the characters of that knowledge. As shown in Table 1, knowledge is codified if it is expressed in a digital form or in software or is science-based. It is tacit if it is expressed in an analog form or in hardware, or is skill-based.

These days knowledge has become more codified. Since technology has become more science-based, knowledge to be transferred in technology transfer has become more codified and can be expressed in documents. Since information technology has advanced coupled with microelectronics technology development, knowledge is stored in software or microchips. This phenomenon also makes knowledge more codified.

Thus, technology transfer needs less human involvement nowadays since tacit knowledge transfer requires human involvement. This implies that technology transfer has become easier in a sense and more unified.

However, knowledge related to analog character, hardware or skill-based, tacit knowledge plays an important role. In Japan, technology transfer is carried out through human transfer in many occasions.9 Tacit knowledge, which is hard to transfer without human involvement, gives a person or a company competitive advantages.

3. Changed Technology Strategy

Technology is changing and innovation means changing. The ever-changing efforts are required for firms and governments to make use of technology and innovation. The accelerated innovation requires quick response and constant “strategy innovations” for firms and “policy innovations” for governments (Figure 4).

3.1 National Technology Strategy

3.1.1 From Public Initiative to Private Initiative

In the former days, R&D mission was clear and the public sector took initiative and developed technology itself to some extent. However, the mission is now diversified and it is difficult to determine. The private sector knows market needs better since companies operate in the market and compete each other everyday. Thus, the private sector should be a main

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9 See Kusunoki and Numagami (1997).
player of technology development. Technology development mode needs to be shifted from technology-push to market-pull.

In order to do so a more vigorous national strategy is needed to develop R&D capability in the private sector because R&D capability is concentrated in public sector in most of developing countries. It is needless to say, however, that a public role is definitely important to assist and complement the private sector R&D. The government is responsible for intellectual property right (IPR) protection to facilitate private R&D and technology import, constructing science and technology databases that are public goods, setting standards for facilitating industrial networking and so on.

Though science and technology policy in developing countries places a strong emphasis on public R&D, supporting services are increasing their roles. Though public R&D is surely needed to assess and assimilate technologies acquired and is needed in some areas, such as environment and safety, more resources and policy attention need to be oriented to supporting services such as testing, consulting, information provision and training.

Upgrading the average level of industrial technology of a country is an acute problem. However, supporting institutions to improve technological level are not well developed in developing countries. Even the United States developed extension service organizations through Manufacturing Extension Partnership (MEP) Program, which modeled itself on the Japanese Kosetsushi system (see Box 2).

3.1.2 From 'Research for Research' to 'Assistance for Industry'

It is commonly seen that science and technology policy in developing countries places a strong emphasis on R&D. For R&D, faculty members and researchers, many of whom are trained overseas, have a stronger linkage to international scientific community than to domestic industry and most of research seems to aim at producing papers in academic journals. More resources and attention need to be oriented to industry. A country cannot afford to allow researchers to enjoying a paradise in their circles. Researchers need to contribute to economic development of the country in the age when competition is global and technology is a critical element of competition.

Another common phenomenon seen in the developing countries is emphasis on science. This is partly due to the fact that scientists are respected and influential and the fact that engineers are not influential yet. Science is indeed important for education and a basis for technology development in a long run. However, a country needs to meet more immediate technology development demands to compete in an international market. Policy emphasis needs to be shifted from science to technology since science differs from technology (Figure 5).

Policy emphasis also needs to be shifted in education between science and engineering. Resources need to be shifted from science departments of universities to engineering departments or technology institutes to support technological development of a country, although the demarcation between science and technology is blurred in some areas such as biotechnology.
3.1.3 From General Financing to Tailored-For-Technology Financing

Changes are occurring in financing, too. Conventional loans are risk averse and technology assets are not safe as collateral. Thus, new risk financing schemes are emerging. One is a form of venture capital. A government needs to assist this new scheme to be developed.

Another is a form of conditional loans. A government needs to provide conditional loans to risky technology development projects in addition to conventional loans. Or a government provides R&D grants such as Small Business Innovation Research (SBIR) Program in the United States.

Moreover, traditional financial institutions do not possess proper capabilities to assess technology assets. It is also needed to establish new financial institutions that are technologically capable and are specially catered for technology-related risk financing.

3.1.4 From Formal Education/Training to Practical Education/Training

Education also needs some changes. In the former days one-time education was enough. Knowledge needed after education could be acquired by individual efforts and on the job experiences. However, as technology increases its speed of development and its knowledge content, it requires more systematic continuing education for people to catch up with ever changing technology. Education is changing from one-time education to lifetime continuous learning. A national strategy needs to assist develop the change of a formal education system and informal training or learning institutions.

Though higher education is important, at the same time, basic education and vocational training are important to secure the basic level of industrial technology of a country as seen in East Asian countries until basic education becomes pervasive.

Training also needs to be changed. Firms know their training needs best. In Japan, in-house training is common and extensive based on a long-term employment practice. Public training may provide generic training but not tailored for each firm or each industry. Moreover, once a public institute is established, its management is rigid. It is not easy to change trainers and machines for training frequently, though technology changes quickly and firms need to equip with up-to-date technology to compete internationally. Thus, training needs to be shifted from public-led training to firm (or industry)-led training. When training is done in firms, their up-to-date machines can be used for training and their senior workers act as trainers. One training institute in Malaysia provides a good example of industry-led training (see Box 3).

3.2 Corporate Technology Strategy

3.2.1 From Self-Reliance to Networking

A major change in corporate technology strategy is from self-reliance to networking. Technology development activities were mostly conducted in-house in the former days. However, in-house development only is not enough to cope with the accelerated speed of technology development and with a new and wide range of technologies. Thus, firms need to seek partners for technology development to complement quantity and quality of engineers.
They make strategic alliance with other firms, sometimes even with competitors. They also cooperate with universities and government institutes. They need to compete not as an isolated point but as a node of a network. Networking partners are not only domestic partners but also international.

Firms also make an international alliance to establish de facto standards of new products. When a firm develops a new generation product, the industrial standards of that product largely determine the competitiveness of that firm. If the specification of the type of a product that firm is developing is adopted as an international standard, it will give a strong competitive advantage to that firm. Otherwise, that firm will lag behind in an R&D race of that product and needs to pay a large amount of royalty to a firm whose product specification is adopted as an international standard.

Also for production, firms need to compete as a network. This strategy gives flexibility and agility of new product production as far as partners deliver quality products just in time. Subcontract arrangement based on a long-term relation has been largely seen in the Japanese assembling industries. Work specialization and sharing network is seen in the Italian fashion industry. Today, this kind of production network is worldwide. Some firm has only design and marketing function. They are fabricationless companies.

For firms in developing countries, it is quite advantageous to be in the international production network. They may be original equipment manufacturers (OEMs), subcontractors or subsidiaries. They can access to or are exposed to foreign technology, management skills and marketing information constantly.

### 3.2.2 From Single Approach to Comprehensive Approach

Borderless economy inevitably creates mega-competition; and this mega-competition has changed the mode of competition. Beforehand operational competition was mostly based on price because competitors were basically domestic and their product quality was similar. For timely delivery, old logistics management and transportation did not allow speedy production of ordered products. Thus, competitors pursued competitive advantages through economies of scale or other means to lower price.

Now operational competition is based on speed, quality and function in addition to price. Thanks to the advancement of information network and transportation network, buyers and consumers can obtain product catalogues quickly, order instantly and receive products timely. Since customers are accustomed to getting products that they want quickly, they change their tastes for goods quickly and prefer to have new differentiated goods from others. Thus, the time required from design to delivery also needs to be shortened. In Mauritius and Cyprus, fashion sensitive fabrics are sent by air from Europe.

For quality, many competitors from the world provide different qualities of goods. Then, buyers and consumers are conscious about product quality. In addition, an international market, especially European market, requires suppliers to be certified as ISO 9000 factories. ISO 9000 is a set of industrial standards for quality assurance systems developed by International Organization for Standards (ISO). Thus, quality is an important factor of competition.

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10 See Kondo (1995) for the increase of joint patent application in the 1980s in Japan.
Because of accelerated pace of innovation, products with new features and functions appear quickly. In addition, the information of new products travels quickly via Internet and other means. Thus, the function or feature of a product is an important competition factor.

The situation changed for innovative competition, too. Beforehand product development only sufficed in many cases. A new product usually enjoyed its monopoly for a while. However, these days new competitive products quickly appear from some corner of the world and from another industry due to the accelerated pace of innovation and high speed of information diffusion. Thus, a product development cycle of idea creation to market entry needs to be shortened.

Moreover, a total procurement-product-delivery system should be strategically designed from the product development stage. Factors from design to input material procurement and to production and delivery need to be considered to capture profits in a short time and to construct operational competitiveness from the beginning of a new product launch. A business model development is also needed at the time of product development in some areas.

Because of network production and combined usage of products, standards and interfaces are critically important. Firms try to have an initiative in standards setting and interface setting. De facto standards strategy or interface strategy needs to be formulated at the product development stage.

4. Technology Acquisition from Overseas

4.1 Technology Acquisition

Technology acquisition from overseas, technology import, plays a more important role at the early stage of economic development than at the later stages, while domestic technology development increases its importance as an economy develops. Many developing countries largely benefit from importing readily available technologies from abroad to complement their technological capability. As late comers, they can use already-established technologies existing overseas. In Japan, the role of technology import was large at the early stage of its economic development and diminished as it developed. In the early 1960s, technology import payment occupied 14 percent of total technology expenditure, which was the sum of domestic R&D expenditure and technology import payment; however, it decreased to 7 percent in the late 1970s (Figure 1).

To acquire technology, a certain level of technological capability is needed. An entity to acquire technology from abroad first needs to know where to seek candidates of technology to be imported. Then, it must assess each technology and compare those candidates. This kind of capability is often lacking in the firms of developing countries.

In searching technology, there is a structural problem in the market to make the situation worse. Technology market is essentially incomplete. A seller does not want to give details because technology is essentially information. A buyer cannot get enough knowledge of that technology and of required conditions to utilize that technology.

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11 See JITA(1986), page 9. Technology import payment is only for patent licensing, know-how transfer and technology services.
Technology transfer can occur between various types of entities: from university to university, from research institute to research institute, from firm to firm, from university to research institute, from research institute to firm, from research institute to university, from university to firm, from firm to research institute, and from firm to university. However, commercial industry-related technology transfer occurs from firm to firm. To use imported technology for industrial development speedily, the private sector should take an initiative to acquire technology from overseas. Other routes are mostly non-commercial technology transfer routes. They are academic exchanges and official development aids (ODA). They are rather R&D cooperation rather than technology transfer.

4.2 Technology Acquisition Means

There are various means to acquire technology from abroad (Table 2). A comprehensive form of technology acquisition is FDI. FDI brings in not only technology but also management skills and market connections as well as capital. Similar comprehensive means is build-operate-and-transfer (BOT) arrangement. Foreigners build, manage and operate plants or other large projects until they recover their investment. Means like own equipment manufacturer (OEM) arrangement, own design manufacturer (ODM) arrangement and parts production subcontracting also accompany technology import

In China, a variation of OEM, cooperative production is exercised. Chinese firms receive technology from contractors from overseas and produce products for them. Chinese firms also produce products under their brands using the same technology for domestic market and a small number of designated countries. They do not pay royalties but provide products at lower price to the contractors under OEM arrangement. Therefore, this is a combination of OEM and restricted licensing.

For a tangible form of technology acquisition, importing turn-key-plants is the most comprehensive. Importers only need to operate based on manuals. Other tangibles to be imported include capital equipment, products, such as molds, and parts and raw materials. Based on product import, copying and reverse engineering can be performed.

For an intangible form of technology acquisition, there are forms of licensing, know-how transfer and technology services. Other intangible forms of technology acquisition are consulting service, information service and subscription of journals and the purchase of other documents. These activities are mostly related to information purchase.

Human exchanges also bring in technology. Foreign experts are hired to transfer technology. In the late 19th century Japan hired many foreign experts; and their salaries were higher than those of ministers in some cases. Studying and training overseas is a good means to absorb technology overseas. Just visiting foreign factories and attending international fairs also provide good opportunities to get to know foreign technology.

\[12\] Subcontracting means a contract to produce some part of an assembled product or the assembled product itself for other company’s brand. OEM is a type of subcontracting providing a complete assembled product for other company brand based on a provided design. ODM is similar to OEM except detailed design done by a subcontractor.
To facilitate and promote technology acquisition from overseas using various means described above, policy efforts are required. Policy instruments used depend on an acquisition means. For a comprehensive means, such as FDI, even a macro economic policy is important (Table 3). For a specific means, such as licensing, a particular technology policy, such as IPR protection, is important.

4.3 Comparison of Technology Acquisition Means

To acquire technology from overseas, different countries adopt different means such as FDI, OEM and licensing. For example, Japan mostly used licensing and technology services, Chinese Taipei used OEM and other types of subcontracting and Singapore and Malaysia used FDI.

There are clear differences among those acquisition means. Each of the three means has both advantages and disadvantages (Table 4). FDI requires only basic skills and brings in capital, management skills, market link and technology. To start industrialization, FDI is the easiest way to enter an international market though basic infrastructure and political and macroeconomic stability are needed. However, management decision is entirely in foreigners’ hands and may be foot-loose. If labor cost increases, FDI may move to lower labor cost countries. FDI usually does not invest in deepening technological capacity of local subsidiaries unless local subsidiaries become world centers of some products.

OEM or other types of subcontracting are widely used to acquire technology and market. OEM involves various levels of technology transfer from providing blue prints and specification of products only to providing production machinery, know-hows, key input materials and worker training. OEM accompanies licensing in many cases. The subcontracting in Japan sometimes accompanies financing as well as technical assistance. Assembling firms sometimes provide financing for new production equipment to produce parts for them.

OEM requires existing companies to possess capital and management capability including production management capability. Since market is provided, the risk to start business is small but profit margin is also small. Management decision of a subcontractor affects the management of a subcontractee largely. An OEM manufacturer has an incentive to move to ODM and own brand manufacturing (OBM) to increase profit margin and gain management autonomy. The possibility of future growth is fairly large.

Licensing brings just technology. Sometimes licensing is just paying royalties. A firm is capable to produce a certain product without further information but it has to pay royalties because of a patent right owned by the other firm. Licensing requires high management and technology potentials for licensees. Even though licensing provides more elaborate technical assistance, a licensee must have or create a market access and bear the whole business risks. If a licensee markets products successfully, its profit margin is large. Since a licensee possesses management autonomy, it has a great incentive to make efforts to develop technology and a high possibility to grow.

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13 See Hobday (1997) for benefits and disadvantages of OEM/ODM in South Korea.
The choice of technology acquisition strategies differs depending on technology capability of a recipient country. As noted above, FDI requires the lowest technology capability and management resources; licensing requires the highest technology capability.

The time a country starts industrial technology development also affects the choice of technology transfer strategies. The earlier the timing was, the role of foreign sources was smaller. In the older days it was easier to protect domestic industries from the view of international political economic environment and it was not easy to find right sources and transport their products quickly because telecommunication and transportation were not well developed. Thus, licensing was a good strategy option provided that a recipient country had certain technological capability to assimilate acquired technology.

Now the situation has changed. A single international market is emerging because of the World Trade Organization (WTO) and the development of telecommunication and transportation; and domestic market protection to foster domestic technology capability is more difficult. At the same time, international market access is needed to acquire information of customer needs, technology and suppliers. Moreover, it is getting more difficult to get license from overseas. Firms in developed countries are, on one hand, reluctant to transfer just technology. They prefer to export their products themselves or to invest overseas to get more profits. Because of a Mega-Competition, it has become easier to manage worldwide trade and operation of business. On the other hand, firms in developing countries prefer to enter the international market quickly. Thus, FDI and OEM and other types of subcontracting are more plausible strategy options these days.

5. Technology Acquisition and Technology Development

5.1 Three Modes of Technology Development

Three ways can be considered to improve technological level of a country:

(i) Introducing technology abroad,
(ii) Improving existing technology and
(iii) Developing new technology indigenously by formal R&D or production experience.

This section proposes a progressive model of technology development (Figure 6). This model progresses from acquisition to assimilation and diffusion to indigenous development (improvement and innovation). These modes exist at the same time in an economy, though the emphasis on each mode differs from an economy to an economy depending on a development stage and strategy.15

Though all the three modes of technology development need to exist, at the early stage of development, technology acquisition is most important. That is, technology transferred from overseas is a major source of technology in developing countries. An assimilation mode is also important to fully utilize imported technologies. Then, this technology is

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14 See Dahlman et al. (1995).
15 Dahlman and Brimble (1990) used an analytical framework of acquiring foreign technology, using anddiffusing technology, improving and developing technology and investing in technical human capital. Bjerke(2000) says that Japan progressed in the following order: imitation, improver, improviser, innovation andinvention.
utilized in developing countries. Finally, this technology is improved and based on this technology new technology is developed. Of course technology is developed from other sources such as findings in universities.

5.2 Assimilation of Acquired Technology

Assimilation is usually achieved to a certain level if a technology is acquired through comprehensive means. In this case, a technology supplier makes sure that an imported technology work for its own sake. The technology supplier will lose profits or reputation if a transferred technology does not work.

Using imported technology through licensing is, however, not easy. It took a longer time and required higher R&D cost to develop a new product with imported technology than with in-house technology in Japan, though revenues from new products with imported technology were large. It took, on average, 2.50 years and 680 million yen at the 1963 price to develop a new product with imported technology, whereas it took, on average, 2.35 years and 170 million yen with in-house technology (Table 5).\(^\text{16}\)

Japan’s experience demonstrated that technology import must be accompanied by domestic R&D to assimilate the imported technology. In Japan, domestic R&D expenditure paralleled the increase of technology import from the early 1950s.\(^\text{17}\) Domestic R&D does not mean scientific research conducted in universities or national research institutes. It means, rather, to experiment in firms with what technical documents state, changing some parameters or downsizing the scale of plants to adapt imported technology to domestic conditions. It means to experiment with ideas like Columbus’ egg to make incremental innovation based on imported technology.

In the initial industrializing phase, R&D is needed for assessing and selecting foreign technologies to be imported. This role is expected for public research institutes to play making use of their international connections, though they sometimes conduct research for themselves isolated from industry. Public research institutes and universities are expected to assist firms to solve their technical problems or refer some specialists in other places. Equipment suppliers and input material suppliers are also helpful in solving technical problems.


Within a country, technology transfer from universities to firms and from research institutes to firms is important to utilize domestic technological capability for industrial development. In these technology transfer activities, universities and research institutes also benefit from collaboration with the industry.

There are various ways to facilitate collaboration among the industry, universities and research institutes. In Japan national projects are organized to develop technology mostly between the industry and public research institutes. The Very-Large-scale Integrated Circuit Research is one of successful examples.

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\(^\text{16}\) See Agency for Industrial Science and Technology (1963), page 11.
\(^\text{17}\) The correlation coefficient was 0.9848. The data were obtained from JITA(1986), pages 6-8.
These days, Japan makes tremendous efforts to facilitate the collaboration between the industry and universities. The Ministry of Education established “venture business laboratories” to encourage business-oriented research on campus, collaborative research centers to facilitate university-industry research. The Ministry and the Ministry of International Trade and Industry provide research grants to university-industry collaborative R&D projects and assist establishing technology licensing organizations (TLOs) that license university patents to the industry.

Active university-industry collaboration is seen in research papers. Co-authorship between university researchers and company researchers is increasing\textsuperscript{18}. The collaboration is naturally stronger with domestic universities than foreign universities.

Now, a new mode is appearing in Japan. As seen in the United States and other countries, some Japanese professors and students start up companies. Also, some researchers of public research institutes start up companies. The government encourages these activities.

Regional initiatives are also seen in Japan. Kochi prefecture is one of the least developed regions in Japan. The governor of Kochi prefecture established a university of technology to develop manufacturing and software industry. Many professors were recruited from industry. The university has a liaison office and rental laboratories on campus to conduct university-industry R&D. To promote university-industry R&D, research parks or incubators are needed to make firms more accessible to universities and research institutes. Research parks provide better environment for firms to establish their research institutes in the vicinity of universities or research institutes. The university also provides entrepreneurship education to graduate students and holds short courses for the public. Several professors and students have started up companies.

Increasingly important aspect of R&D in developing countries is cooperation among R&D institutions. Since R&D capability is weak in the private sector in developing countries, cooperation between firms and public research institutes or universities and cooperation between multinationals and local suppliers are important for technology development.

To encourage the collaboration among the industry, universities and research institutes in developing countries, the mission statements, funding schemes and evaluation criteria of universities and research institutes must be in that way. Developing countries must avoid one of the biggest technology policy pitfalls found in developing countries, that is, science promotion under the name of technology development.

7. Concluding Remarks

We live in the global age and we can exchange information and goods worldwide easily. We also travel easily. Thus, international networking is easier. Because of the change of the character of technology development, inter-industrial-sector networking and inter-institutional networking are also occurring.

Any country or firm can make use of networking to enhance its competitiveness. There are two points to make. One is that this opportunity is open to any country or firm. If

\textsuperscript{18} See Pechter and Kakinuma (1999) for the increase of university-industry coauthored papers in the 1980s and 1990s in Japan.
a country or a firm does not make use of networking, it will be disadvantageous. Thus, there are no choices whether a country or firm utilizes networking. The other point is that for some networking national or regional networking is more important than international networking as seen in the case of university-industry collaboration in paper writing. Thus, national or regional efforts are critical for networking.

The issue is how to facilitate and support networking. The strategy may differ from country to country. However, there exist a large number of experiences to learn both in developed countries and developing countries. We can access to the valuable information of these experiences thorough networking.
Box 1. Igyoshu Koryu Plaza (Inter-industry-sector Exchange Plaza)

This policy is formulated by Small and Medium Enterprise Agency, the Japanese Ministry of International Trade and Industry, to assist small- and medium-size enterprises (SMEs) jointly to develop new products or new businesses complimenting each other mainly in the area of technological capability. In 1988, the time-limited Fusion Law was enacted to officially support cooperatives consisting of SMEs from different industry sectors.

This policy was well used. Until the end of 1997, 317 cooperatives with concrete business ideas were established based on this Law and received public assistance. Nearly 3,000 groups consisting of nearly 125,000 SMEs participated in this activity in 1997. These groups are organized locally with some coordinators. Local chambers of commerce and industry could be coordinating agencies. One member from the same industry sector is admitted in one group to avoid conflicts. Members freely discuss issues and ideas they have and sometimes visit their factories. Occasionally, some of members come up with new business ideas and they eventually establish a cooperative to develop new products.

Box 2. Kosetsushi (Public Research Institutes) of Japan

In Japan, all prefectural governments and some municipal governments operate public research institutes called “Kosetsushi”, which means public testing laboratories. There exist 602 such laboratories in 1999. Though the majority of them are for agriculture, a substantial number, 185, of them are for the secondary industry.

The main mission of these laboratories used to be testing and measurement to issue certifications. It has shifted to R&D. At the same time, these laboratories consult local small- and medium-size enterprises (SMEs) and provide solutions to their technical problems.

Also, they function as the information gateway of SMEs. When the laboratories can not provide enough information, they contact national research laboratories and universities. They are in such a network.

The US Federal Government found that the extension service function of Kosetsushi is valuable. It started Manufacturing Extension Partnership (MEP) Program cooperating with State Governments. According to an evaluation study, the survival probability of the SMEs that received MEP service was higher than that of the SMEs that did not receive MEP service.

Box 3. Penang Skill Development Center (PSDC) ²⁰

This PSDC is basically managed by large local firms with the supports from a local government. Its land and building are provided by the local government, but the Center is essentially managed by managers of the large local factories. Those managers decide training curricula.

The management is efficient and training fees are around half of those of commercial institutions. Training equipment is leased, sometimes without charge, from equipment vendors to the factories in that region. As the center functions as a showroom of equipment vendors, the newest models are set all the time. For trainers they are hired on a term-by-term basis to meet changing demands from local firms.

This institute meets the needs of local industry at an affordable training fee and keeps flexibility of training curricula through public-private collaboration.

²⁰ See Kondo (1999).
References


### Tables

#### Table 1. Knowledge Classification

<table>
<thead>
<tr>
<th>Codified</th>
<th>Tacit</th>
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<tbody>
<tr>
<td>Form</td>
<td>Digital</td>
</tr>
<tr>
<td>Medium</td>
<td>Software</td>
</tr>
<tr>
<td>Base</td>
<td>Science-based</td>
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</tbody>
</table>

#### Table 2. Technology Acquisition Means

<table>
<thead>
<tr>
<th>Means</th>
<th>Comprehensive</th>
<th>Tangible</th>
<th>Intangible</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Technology import, Licensing, Know-how transfer</td>
</tr>
<tr>
<td>FDI</td>
<td></td>
<td></td>
<td>Technology service, Information purchase</td>
</tr>
<tr>
<td>BOT</td>
<td></td>
<td></td>
<td>Consulting service, Information service, Journals</td>
</tr>
<tr>
<td>OEM</td>
<td></td>
<td></td>
<td>Human exchanges, Attending fairs</td>
</tr>
<tr>
<td>ODM</td>
<td></td>
<td></td>
<td>Hiring foreign experts, Overseas study and training</td>
</tr>
<tr>
<td>Subcontracting</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Surn-key-plants</td>
<td>Capital equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Products such as molds</td>
<td>Products for reverse engineering</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Parts and raw materials</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Technology import</td>
<td>Licensing, Know-how transfer, Technology service</td>
</tr>
<tr>
<td>Means</td>
<td>Policy Instruments</td>
<td></td>
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<td>-----------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
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</tr>
</tbody>
</table>
| FDI (Foreign Direct Investment) | Macroeconomic stability  
Political stability  
IPR protection  
Information service  
Information centers  
Information telecommunication network  
Network creation  
Promoting agencies for FDI  
Administrative services  
One-stop-office (FDI and business start-up)  
Work permit administration  
Custom clearance system  
Business support services  
Umbrella scheme  
Ports, airports and roads  
Industrial estates  
Lease factories  
Tax holidays  
Special economic zones  
No foreign capital ratio regulation  
No limits on overseas remittance of profits  
No limits on the ratio of IPR value in equity |
| BOT (Built, Operate and Transfer) | Macroeconomic stability  
Political stability  
No limits on overseas remittance of profits |
| OEM (Own Equipment Manufacturer) | IPR protection  
Commercial legal system |
| ODM (Own Design Manufacturer) | Training service  
Training institutes  
Information service  
Information Centers  
Accreditation and certification service  
National MSTQ system especially for ISO 9000  
Networking service  
Promoting agencies for exports  
Administrative service  
Custom clearance system  
Business support service  
Information telecommunication network  
Ports, airports and roads |
<p>| Subcontracting         |                                                                                                                                                                                                                       |</p>
<table>
<thead>
<tr>
<th>Technology import</th>
<th>Market competition</th>
<th>IPR protection</th>
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</thead>
<tbody>
<tr>
<td>Licensing</td>
<td>Consulting</td>
<td>Commercial legal system</td>
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<td>Know-how transfer</td>
<td>Network creation</td>
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<td>Technology service</td>
<td>Public research institutes as technology transfer agents</td>
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<td>Information purchase</td>
<td>Information service</td>
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<td>Consulting service</td>
<td>Information Centers</td>
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<td>Information service</td>
<td>Administrative services</td>
<td>Proper technology transfer administration</td>
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<tr>
<td>Journals</td>
<td>Tax incentives including reduced tariff rates</td>
<td></td>
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<tr>
<td></td>
<td>Matching grants for information purchase and consulting</td>
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<td></td>
<td>Royalty rate regulation and remittance overseas</td>
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<table>
<thead>
<tr>
<th>Human exchanges</th>
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<th>Network creation</th>
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<tr>
<td>Attending fairs</td>
<td>Export promoting agencies</td>
<td>Information service</td>
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<td>Hiring foreign experts</td>
<td>Information centers</td>
<td>Administrative services</td>
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<tr>
<td>Overseas study and training</td>
<td>Work permit administration</td>
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<tr>
<td></td>
<td>Tax incentives</td>
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</tr>
<tr>
<td></td>
<td>Matching grants for attending fairs, hiring foreign experts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and overseas study and training</td>
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<table>
<thead>
<tr>
<th>Tangible imports</th>
<th>Market competition</th>
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<tbody>
<tr>
<td>Turn-key plants</td>
<td>Information service</td>
<td>Information Centers</td>
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<tr>
<td>Capital equipment</td>
<td>Administrative services</td>
<td>Custom clearance administration</td>
</tr>
<tr>
<td>Products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input materials</td>
<td>Tax incentives including reduced tariff rates</td>
<td></td>
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<tr>
<td></td>
<td>Local content regulation</td>
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</tbody>
</table>

Note. IPR: intellectual property right.
MSTQ: metrology, standards, testing and quality.
### Table 4. Comparison of Means of Acquisition

<table>
<thead>
<tr>
<th></th>
<th>FDI</th>
<th>OEM and Subcontracting</th>
<th>Licensing</th>
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<tbody>
<tr>
<td>Assets acquired</td>
<td>Capital Management Skills</td>
<td>Market link Technology</td>
<td>Technology</td>
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<tr>
<td>Required capacity</td>
<td>Basic</td>
<td>Middle</td>
<td>Advanced</td>
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<tr>
<td>Risk of entry</td>
<td>None</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Subordinateness</td>
<td>High</td>
<td>Middle</td>
<td>Low</td>
</tr>
<tr>
<td>Profitability</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
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<tr>
<td>Growth possibility</td>
<td>Low</td>
<td>Middle</td>
<td>High</td>
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</table>

### Table 5. Cost to Develop a New Product Using Imported Technology and In-House Technology in 1963

<table>
<thead>
<tr>
<th></th>
<th>R&amp;D Expenditure per Product (100 million yen)</th>
<th>Time Required (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imported Technology</td>
<td>6.8</td>
<td>2.50</td>
</tr>
<tr>
<td>In-House Technology</td>
<td>1.7</td>
<td>2.35</td>
</tr>
</tbody>
</table>

FIGURES

Figure 1. Technology Progress and Technology Import in Japan

Technology import ratios: the author.

Figure 2. Technology, Economic Activities and Networking

<table>
<thead>
<tr>
<th>Technology</th>
<th>Economic Activities</th>
<th>Networking</th>
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<tbody>
<tr>
<td>Development of Information Technology</td>
<td>Borderless Economy</td>
<td>International</td>
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<tr>
<td>Communication Technology</td>
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<td>Transportation Technology</td>
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<td>Technology Fusion</td>
<td>Sectorless Competition</td>
<td>Inter-sectoral</td>
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<td>Acceleration of Technology</td>
<td>Corporate-boundaryless</td>
<td>Inter-institutional</td>
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<td>Development</td>
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<td>Business</td>
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<tr>
<td>Science-based Technology</td>
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</tbody>
</table>

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Figure 3. Technological Alliance between Firms (1992-1995)

Figure 4. Paradigm Shift of Technology Strategy

**National Strategy**
From Public Initiative to Private Initiative
- Public Technology Development → Private Technology Development
- R&D Capability → Infrastructure Building (e.g. IPR Protection, S&T Database, Standards and Metrology)
- R&D Focus → Supporting Service (e.g. Consulting, Testing and Information Provision)

From ‘Research for Research’ to ‘Assistance for Industry’
- R&D for Journal Papers → R&D for Industry
- Science → Technology/Engineering

From General Finance to Tailored-For-Technology Finance
- Conventional Loans → Venture Capital and Conditional Loans
- Conventional Financial Institutions → Technologically Capable Special Financial Institutions

From Formal Education/Training to Practical Education/Training
- One-Time Education → Life-Time Continuous Learning
- Higher Education → Primary/Secondary Education and Vocational Training + Higher Education

**Corporate Strategy**
From Self-Reliance to Networking
- Formation
  - In-House Efforts Only → Network Sourcing
- Space
  - Domestic Network → International Network

From Single Approach to Comprehensive Approach
- Operational Phase
  - Price → Speed, Quality and Function + Price
- New Product Development Phase
  - Product Development → Procurement-Production-Marketing System/
    Business Model/Standards or Interfaces + Product Development
Figure 5. Science vs. Technology

Figure 6. A Progressive Model of Technology Development