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Promoting industrial development through technology policy: Lessons from Japan and China

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Abstract

In this paper, we analyzed and compared how Japan and China's technology policies have contributed to their industrial development. Using numerical methods, we found that technological capability has contributed to both countries' industrial development and upgrade in their peak-growth period. Further, the governments of both countries have intentionally promoted domestic technological capability by effective technology policies, balancing the import of foreign technology and indigenous development, and engaging business/private sector as a major force for improving technological capabilities.

We thus offer the following policy recommendations to the governments of developing countries: (1) being aware of the important and appropriate role of government and existing policy tools, (2) adopting for the localized option that fits the country's specific social-economic reality; and (3) utilizing import of foreign technology and indigenous development and developing market mechanisms to encourage private sector engagement.

Keywords: Japan; China; Technology policy; Industrial development

1. Introduction

In today's economy, knowledge has become an increasingly important production factor. Using 45 countries' data in 1999 [1], we found that a relative strong correlation

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exists between the percentage of GDP spent in research and development (R&D) and GDP per capita (R^2 value of 0.63). Science and technology (S&T) are critical for development: ignoring their importance is short-sighted—it only makes the gap between the developed and the developing world larger. Luckily, there are signs that S&T is increasingly part of the agenda of both the international community and policy makers in developing countries.

At last, leaders from developing countries have started to turn their attention to S&T development. For instance, President Musharraf of Pakistan expressed deep concern over the low level of scientific knowledge, particularly in Muslim countries. He called for the creation of a fund for education development, with a particular focus on science and technology [2]. This foresight and determination is in direct contrast with the short-term vision of leaders in the developing countries in the past.

Furthermore, some developing countries have already started to use S&T as an alternative pathway for development. From the Newly Industrialized Economies (NIEs) such as South Korea, Singapore, and Hong Kong, to the recently emerging countries such as China, Malaysia, and India: all have aggressively pursued a policy of development of technological capabilities. Malaysia, whose world competitiveness was ranked as No. 4 in 2003, has shown to the rest of the developing world how S&T can spur economic growth [3].

The private sector has also joined the international effort to reduce the divide between the developed and developing countries. Improving developing countries' technological capability has been increasingly viewed as a valid alternative to financial aid. In January 2004, the United Nations Development Program (UNDP) and Microsoft Corp. announced a technology partnership to create and implement information and communications technology projects that will help developing countries achieve the Millennium Development Goals. Microsoft has committed $1 billion in cash, software, curriculum, and technology assistance over the next five years to help reduce the global digital divide. The partnership aims to help the capacity building of the developing countries through advanced technology [4].

With national policy makers starting to take notice and international resources becoming available, what options are there for developing countries to effectively develop their technological capability? A review of the literature on S&T for development reveals a range of contrasting views on issues such as: Has foreign direct investment had a positive impact on technology development? How do you balance technology transfer and indigenous development? How do you utilize industrial clustering and networking, globalization and internet for development? [5–7].

The role of government in technology capability development is particularly contentious, since weak institutional settings are the usual drawbacks of developing countries. In particular, the lack of sound technology policy to guide the development of technological capability of industry is common in most developing countries.

In this paper, we provide two countries' experience in technology policy and industrial development and hope it will help policy makers in developing countries have a better understanding of how governments can get involved in industrial development through effective technology policies. Japan sped up its economic growth in the 1950s and has since become one of the strongest economies in the world. China has amazed the world with its stunning GDP growth rate since it launched its economic reform in the 1980s. Both countries are successful examples of catching-up through technology development, albeit in different time periods and to different degrees. This paper intends to empower developing countries' ability to learn, to absorb, and to improve, i.e., to learn from successful experiences, to absorb those experiences into their own institutional settings, and to improve their abilities in creating self-sustained S&T policies that are instrumental to their development. We thus intend to address the following research question: How have technology policies contributed to Japan and China's industrial development and what can other countries learn from their experiences?

Using numerical methods, we found that technological capability has contributed to both countries' industrial development and upgrade, as shown by total factor productivity (TFP) of Japan (1960–2000) and China (1983–2000). Further, the governments of both countries have intentionally promoted domestic technological capability by effective technology policies. Our analysis focuses on three aspects: (1) responding to their national needs and envisioning the long-term goals, how have both governments created policy dynamics that have guided their industrial development? (2) How have both governments utilized both technology imports and indigenous technology development to improve their technological capability? (3) How have both governments engaged different role-players (public and private, research and business communities) to improve their technological capability?.

2. Contribution of technology progress to economic development

2.1. Economic growth of Japan and China

In the post-World War II era, Japan created the "miracle" that astounded the world by quickly recovering from the ruin and developed itself into the second largest economy in the world. From 1960 to 1990, its GDP and GDP per capita increased rapidly with a growth rate of 6.2% and 5.3%, respectively. However, Japan's economy slowed down in the 1990s after the bursting of its bubble economy, which was reflected by the low growth rates of GDP (1.2%) and GDP per capita (0.9%) in the 1990s. China rapidly developed its economy after market reform in the 1980s with a very strong GDP; GDP per capita growth rates were around 9% (Fig. 1).

2.2. Technology's contribution to economic growth

The growth of GDP has been used widely to indicate the speed of the economic development of a country and we here adopt the production function to explain the sources of growth for Japan and China. The production function incorporates labor, capital, and technology as their production factors: $Y = F(L, K, T)$; where Y stands for GDP, L stands for labor, K stands for capital, and T stands for technology stock. Thus, the increase rate of GDP can be written as following:

$$\frac{\Delta Y}{Y} = \frac{\partial Y}{\partial L}\frac{L}{Y}\frac{\Delta L}{L} + \frac{\partial Y}{\partial K}\frac{K}{Y}\frac{\Delta K}{K} + \frac{\partial Y}{\partial T}\frac{T}{Y}\frac{\Delta T}{T}, \tag{1}$$

where $\Delta Y = \mathrm{d}Y/\mathrm{d}t$.

The above equation explains that the growth of GDP can be decomposed into three parts: the contribution of the capital, labor, and technology.

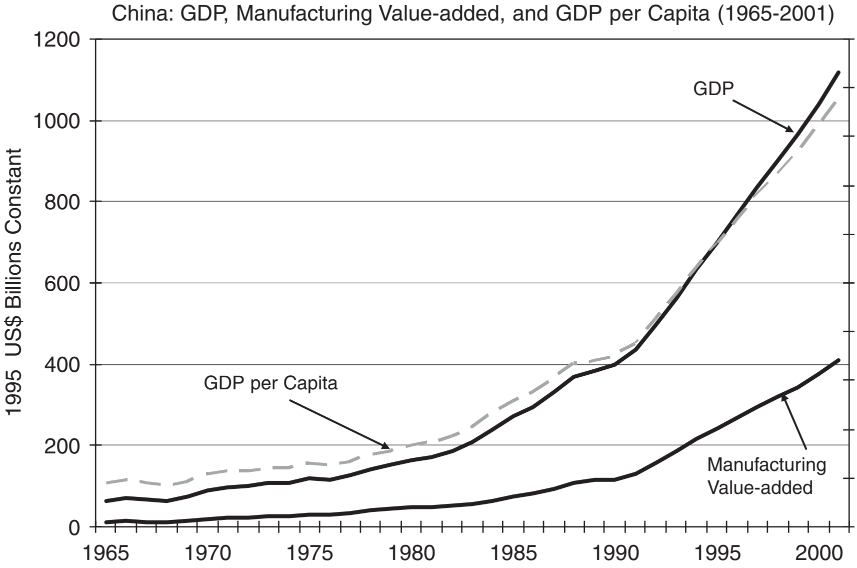

Fig. 1. China's GDP and manufacturing value-added (1965–2001) source: World Bank [1].

Eq. (1) can be also rewritten as

$$\frac{\Delta Y}{Y} = \frac{\partial Y}{\partial L}\frac{L}{Y}\frac{\Delta L}{L} + \frac{\partial Y}{\partial K}\frac{K}{Y}\frac{\Delta K}{K} + \frac{\partial Y}{\partial T}\frac{R}{Y}, \tag{2}$$

where R stands for R&D expenditure.

The contribution of technology progress can be measured by TFP growth rate,[1] the last term of Eq. (2). In this paper, we evaluate the contribution of technology progress to Japan and China's economic growth by means of TFP growth rate. Here we directly used the analysis result from OECD (1988 and 2001) [8,9] to demonstrate Japan's case; while we compute TFP growth rate for China.

Decomposing Japan and China's GDP growth into the three factors' contribution reveals that technology has contributed significantly to both countries' economic development, especially during their high growth periods. OECD's analysis (1988 and 2001) [8,9] indicates that starting from the 1960s, the contribution of technology to GDP growth conspicuously increased up until the 1980s, but then dramatically decreased in the 1990s. Japan's growth was mainly due to technological progress from the 1960s to the 1980s, especially in the 1960s, when technological progress led GDP to grow at 6.1% annually, while labor and capital led GDP to grow at 3.5%, which made a total 9.7% GDP growth rate, similar to China's current economic growth rate. While in the 1970s and 1980s technology continued to play an essential role in sustaining Japan's growth, in the 1990s, technology progress was a marginal contribution to the economy, TFP growth rate fell to −0.3% in the early 1990s as Japan entered its post-bubble and economic recession period and its GDP growth rate dropped to around 2% (Fig. 2).

[1]TFP growth rate depends on two factors: marginal productivity of technology (MPT) $\partial Y/\partial T$ and R&D intensity R/Y, as $(\partial Y/\partial T)(T/Y)(\Delta T/T) = (\partial Y/\partial T)(\Delta T/Y)$, and $\Delta T \approx R$.

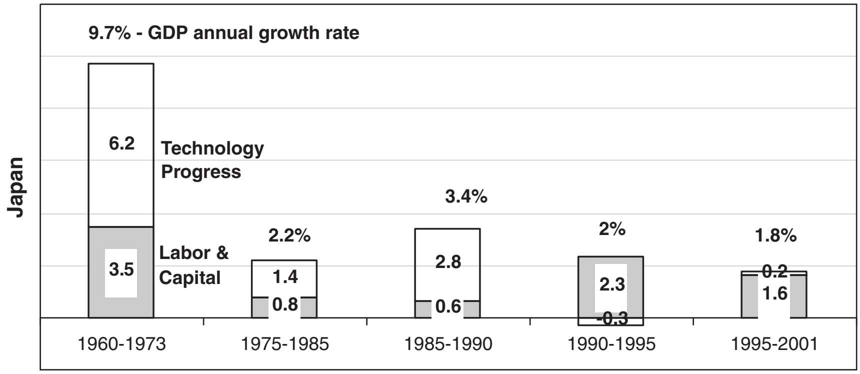

Fig. 2. Contribution of technological progress to economic growth in Japan (1960–2001). *Source*: OECD [8,9].

Similar to Japan, technology progress has contributed significantly to China's economic growth in the last two decades, especially in the 1990s (Fig. 3). At the beginning of the reform era (1981–1985), capital and labor together caused GDP to grow at 5.4% annually, while technology progress caused GDP to grow at 3.9% annually. From 1986 to 1990, technology progress became the leading production factor that contributed to GDP growth. During the period from 1991 to 1995, the average annual GDP growth rate reached 10.7%. This high rate was created mainly through a huge capital injection, which caused GDP to grow at 5.2%, while labor only contributed marginally at 0.8%. Together, they caused China's GDP to grow at 6% annually during the period. Nevertheless, technology progress caused GDP to grow at a 4.7% rate. In recent years, the role of technology progress has been more distinguished. From 1996 to 2000, China's GDP grew at 7.6% annually and technology progress contributed to GDP growing at 5.0% annually.

2.3. High-tech export and patent

High-tech export can be viewed as a direct indicator of economic benefit of the technology progress in the global market. Corresponding to its economic achievement, Japan's success in exporting high-tech products has been impressive, especially during the period before the bursting of the bubble economy in the early 1990s. In the 1980s and 1990s, Japan's high-tech products exportation was kept at a stable 25% of its manufacturing export [1]. Since the 1960s and 1970s, "made in Japan", has been a synonym for high-quality and high-technology for consumers all over the world, especially for the electronic goods consumers. From 1981 to 1992, while US high-tech industry struggled to maintain its global market share, Japanese high-tech industries followed a path of steady gains in their global market share and accounted for nearly 28% of OECD member countries' production of high-tech products, moving up 6% since 1981 [12].

From 1992 to 2001, China's high-tech exports increased more than 10 times within 10 years, from US $4.4 billion in 1992 to US $49 billion in 2001. While in 1992 high-tech products only accounted for 5% of China's overall exports, in 2003, it accounted for a quarter of total exported goods with $110 billion in revenue. China's Vice Premier Wu Yi said that China's policy of "enhancing trade by relying on science and technology" has led to the rapid growth of exports [13].

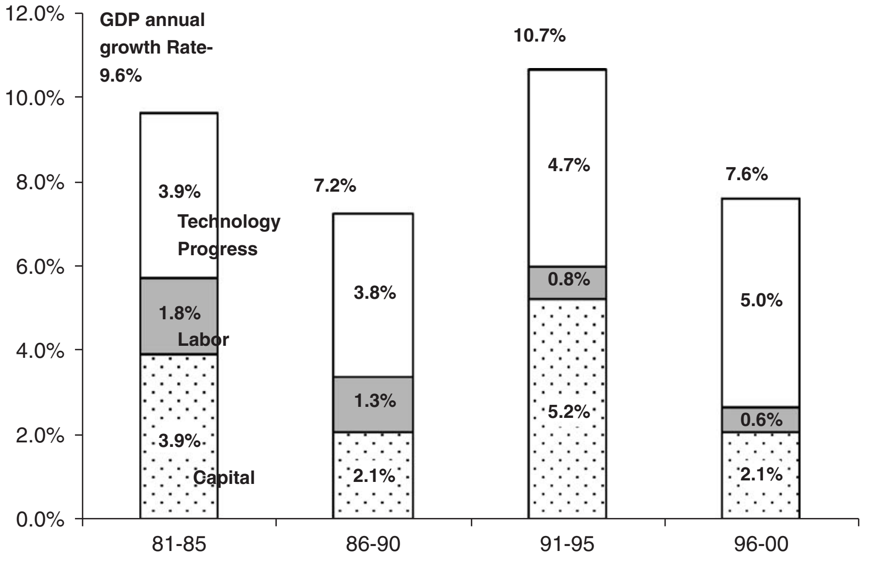

Fig. 3. Contribution of technology progress to economic growth in China (1981–2000). *Sources*: The figures were calculated by the authors based on the following data sources: GDP: World Bank [1], Labor: World Bank [1], Growth Capital Formation Rate: China Statistical Yearbook [10], R&D spending as percentage of GDP: China Statistical Yearbook on Science and Technology [11].

Patent certification, another indicator for technological progress, has continued to grow in Japan and China. For instance, in 1999, Japan's patent certification reached 150,059, only slightly lower than the US (153,487) [14]. During the last decade, China's certified patents have grown five fold. It is also interesting to point out that domestic residents hold nearly half of the invention patents and are the main owners of the other two types of patents (utility model and design patents). Each year, 99–100% of the utility model inventions were granted to domestic residents. Among the non-individuals who were granted the three kinds of patents, universities and colleges were the major owners for invention patents, while industrial enterprises became the main force in the growth of utility model patents as well as design patents.

2.4. Resources for R&D

Here, we would like to focus on two factors that matter in creating technological innovation: financial investment and human resources.

Both Japan and China's achievement of technological capability was closely bounded with their effort in R&D financial input. For instance, in the 1990s, Japan spent an average of 3% of its GDP in R&D, which was ranked as fourth, following Sweden, Israel, and Finland, who spent 3–3.5% of their GDP in R&D. However, the absolute amount of R&D expenditure (US$ 168 billion in 2001) was listed as second, only behind the US [1].

Corresponding to China's average 9% GDP growth rate from 1991 to 2000, China's expenditure on S&T and R&D increased magnificently. R&D expenditure increased from around 0.7% in the early 1990s to about 1.1% in 2001. This figure is still far behind other

Table 1
Scientists and engineers in R&D (per million people)

	China	Malaysia	India	Japan	United States	France	Germany
Scientists and engineers in R&D (per million people)	545 (2000)	160 (1998)	157 (1996)	5095 (2000)	4099 (1997)	2718 (1999)	3161 (2000)
Annual increasing rate	20.7%	9.4%	0.7%	−1.0%	2.1%	16.0%	0.4%
Calculated Period	1994–2000	1993–1998	1990–1996	1990–2000	1980–1996	1990–1999	1991–2000

Source: The authors calculated and summarized based on data from the World Bank [1].

developed countries that generally spend 2–3% of GDP in R&D expenditure. However, China's progress is impressive, considering that R&D expenditure increased even faster than its astounding GDP growth rate. Both the absolute amount and the relative proportion of R&D spending place China ahead of most other developing countries [11].

Further, both Japan and China lead countries with similar economic development levels in R&D human resources. Japan has around 5000 scientists and engineers in R&D per million people, 20% above the technology leader, the US.[2] China had 545 scientists and engineers in R&D per million people in 2001, this figure is only one ninth of Japan and one seventh of the US. However, it led other developing countries such as Malaysia and India by three times. Investigation of the annual increasing rate revealed that China has a distinguished growth rate of 20% of this human resource (1994–2000). Meanwhile, Malaysia and India have growth rates of 9.4% (1993–98); 0.7% (1990–1996), respectively (Table 1).

3. Technology policies for industrial development

Japan and China's development of their technological capability was closely linked with each government's effort in upgrading their industrial infrastructure and economic reform. In this section, we focus on the dynamic involvement of the state in improving technological capability. Further, two other crucial aspects in the process are highlighted: (1) balancing imports of technology with indigenous development and (2) engaging the business sector in R&D.

3.1. The role of the state

3.1.1. Japan

It has been widely acknowledged that the Japanese government has played a very active role in Japan's economic development. The role of the Japanese government is quite

[2]However, starting from 1995, similar to R&D expenditure, this ratio started to drop, which reflects Japan's overall sluggish performance in technological progress. Our calculation, based on the data from the World Bank [1], indicates that compared to other developed countries, France led the annual growth rate by 16%, while the US maintained at 2.1%. Japan, however, showed a decline in its scientist and engineer stock during the last decade and the growth rate fell to −1.0%.

unusual by Western standards in that "it gives Japan an unusual capacity to think strategically and at times to make deliberate changes of direction as a nation society" [15].

The two most distinguished periods of Japan's economic development were the early Meiji period (1868–1890) and the post-war period (1956–1986). From the very beginning of Japan's industrialization in the early Meiji period, it was the State that planned a top-down reform that pushed Japan towards modernization in every aspect of its social-economic life, especially in terms of creating an industrial-capital economy. Details of the State's involvement in Japan's early industrialization in Meiji Period can be found in Sheridan [15] and Preston [16]. In its post-World War II recovery and in later periods, it was also the State that identified national priorities for industrial development, provided guidance and direction, and was directly involved in directing industrial development, especially through the emphasis on improving technological capability.

During the post World War II era, the government formed different sets of industrial policies at different stages of Japan's development and mobilized all available resources to reach their policy goals. In each decade, Japanese government identified key sectors, and technological capability development was centered on those key sectors.

Among all the government bodies, Japan's Ministry of International Trade and Industry (MITI) was the most distinguished one. It "provides industries with administrative guidance and other direction, both formal and informal, on modernization, technology, investments in new plants and equipment, and domestic and foreign competition" [17].

In the 1960s, Japan's industrial policies emphasized shifting Japan towards a heavy (especially steel, car, and machinery) and chemical industrial structure. In 1963, the Industrial Technology Committee of the Industrial Structure Research Council, suggested that in order to transform Japan's economy from one that relied on imported technology to one driven by domestically developed technology, the country must select core technologies to develop. This led to MITI's six research and development projects in the 1960s, with a budget that totaled 5 billion yen in 1970. The government changed laws on industrial property rights to facilitate technology development. Patent Law, Utility Model Law, Design Law, and Trademark Law went into effect in 1960 [18].

In order to satisfy the increasing demand for energy, MITI started the Sunshine Project in the early 1970s to develop and promote new energy-related technology and this project directly supported technology development in solar energy, geothermal energy, synthetic natural gas, and hydrogen energy. It further implemented a law that promoted alternative energy development, along with creating an organization to oversee this development that was designated as a type of special corporation supported by treasury investments, loans, and subsidies [18].

From 1973 to 1985, Japan's economy shifted from a high-growth path to a so-called "stable-growth" phase. The international inflationary environment caused by high-energy prices in the 1970s affected many countries, including Japan, which resulted in the slow-down of the Japanese economy and an increase in the unemployment rate. However, the Japanese government successfully utilized technology policies to encourage the development of energy-saving and less energy-intensive technologies to make Japan's economy less energy dependent. Nevertheless, despite the success in certain technology policies, overall, the government failed to institute the structural reforms to put Japan in a long-term stable growth path [6].

These failures in structural reform were only the prelude to the policy failures of the bubble and the post-bubble period (1985–1999). The huge appreciation of the Japanese yen caused an outflow of manufacturing investment overseas. The government continued its effort to support technology development in the manufacturing sector. However, a heavy regulation and a protectionist mindset have prevented restructuring in non-manufacturing sectors. The failure of the government's policies in those areas has constrained Japan's ability to improve its productivity at national level despite the enormous progress in manufacturing technology [6].

It is worth noting that the R&D consortia organized by the Japanese government has played an essential role in Japan's technology catching up in the 1970s and 1980s and the creation of new knowledge in the 1980s and 1990s. Japanese firms, research institutes, and universities interact with each other through the defined parameters of the consortium. The consortium provides not only training for young researchers, but also opportunities to communicate and exchange information which is difficult to conduct under the long-term employment system of large Japanese companies [19].

Japan's experience reveals that institutional settings can facilitate or impede technology development. While appropriate institutional settings will stimulate innovation (in the 1960s and 1970s); inappropriate institutional settings will impede innovation (in the 1990s).

3.1.2. China

What kind of strategies has the government employed to improve China's technological capability then? The significant contribution of technological progress to economic growth in the second half of the 1990s is closely related to the central government's determination in improving S&T. On May 5, 1995, the State Council announced the "Decision on Accelerating S&T Development" [20]. The decision outlined China's S&T development for the next several decades. It emphasized that S&T research should be closely tied to the market. Instead of designating that all the research should be done at state-owned research institutes, China allowed universities and private industry to conduct research activities as well. This is a dramatic change from the old Soviet-style institutes, which China had implemented in the 1950s. The decision called for the creation of joint ventures with Chinese or foreign venture capitals to accelerate transfer of technology to industry. The decision listed a goal of R&D spending: by 2000, China should spend 1.5% of Gross National Product on R&D. The decision also emphasized protecting the environment and achieving sustainable development and indigenization of S&T creation capability in key areas of manufacturing technology and system design [21].

Before this decision, China had actually already started its S&T system reform mainly through two distinguished national S&T development programs: the 863 Plan and the Torch Program. The National High-tech Development Plan or the 863 Plan aims to foster high-quality fundamental research in China. Considering the prevailing situation in China, a developing country with limited resources for developing different kinds of high technology, the 863 Plan suggested that China should focus on seven areas and 15 topics. The seven areas are biotechnology, astro-technology, information technology, laser technology, automation, energy technology, and new materials technology. The 863 Plan selects experienced scientists and researchers for these issues. As a government organized national science and technology program, the 863 Plan especially encourages participation from domestic enterprises [22].

Projects in the 863 Plan, most of which are basic research (or even pure science), are impractical to conduct at the individual company level because of their high cost/benefit ratio and long (or infinite) time horizon. By participating in national S&T projects, companies can become familiar with the knowledge breakthroughs in the field, thus facilitating higher-level R&D at the company level, such as applied research, exploratory development, and advanced development. The gathering of R&D staff from different companies and universities has helped to form virtual networks among participants, which has stimulated innovation and encouraged idea exchanges, and to some extent has brought results similar to those of physical network clusters [23].

Initiated in 1988, the Torch program aims to make technological development more market-oriented and to facilitate commercialization of technology. Sponsored by the State Science and Technology Commission, the main tasks of the Torch Program include: (1) developing a favorable environment for high-tech industry; (2) setting up high-tech zones and high-tech business start-up service centers; (3) executing Torch projects in seven high-tech industries mainly geared towards market needs; (4) facilitating international cooperation of Chinese firms in high-tech industries; and (5) training high-quality human capital [24].

The role of the government is also reflected in the change of China's national innovation system (NIS), which was explained in detail by Gu [5] and Liu and White [25]. The most conspicuous change in China's NIS is the expansion of the role of primary actors, such as enterprises, since the reform. For example, enterprises expanded their activities in R&D much more than other primary actors [25].

China's NIS reform has focused on its R&D system. After the Cultural Revolution, the government started rehabilitation and expansion of R&D system (1978–1980). From 1981 to 1985, it further elaborated the R&D planning practice. Since 1985, there has been a consensus about market reform decisions for R&D system and thus the government took three steps in the following decade. First, the government advocated that R&D institutes merge with existing enterprises (1987). Further, since 1988, the government encouraged spin-off enterprises from the research institutes and started the Torch program to offer incentives for commercializing R&D products (e.g., establishing new technology enterprises). In the 1990s, the government started transforming established R&D institutes [5].

The merging of R&D institutes with existing enterprises turned out to be a failure because of the inability of the existing enterprises supporting R&D institutes financially. Further, the R&D institutes lagged in technology development compared to other available means for the enterprises getting their technology into the marketplace. However, spin-off technology enterprises have turned out to be very successful, especially in the field of computer technology. The direct transformation of the R&D institutes was a much more comprehensive system reform. In addition to the spin-off technology enterprises, the government also encouraged R&D institutes to establish production centers and consultancy centers that were directly involved in economic activities [5].

3.2. Balancing import of technology and indigenous development

3.2.1. Japan

Japan has extensively used imported technology for its industrial development. However, the Japanese government has also strived to promote indigenous technology development. It is the effective usage of both approaches that has enabled Japan to quickly improve its technological capability.

Japan has long established socio-cultural systems which enabled its smooth and effective assimilation of imported technology. Before World War II (ever since the Meiji period, 1868–1912), technology development in Japan was principally based on, selectively, introducing, adopting, assimilating and developing western technology into the Japanese social and cultural system, without spoiling the indigenous culture. Post-war technological innovation in Japan relied heavily on imported technology and it was one of the factors that led to the high growth of its economy. For instance, a study conducted by the Japanese government in 1961 reported that contributions made by imported technologies to sales were twice as great as the contributions made by domestic technologies [18].

3.2.2. *Why importing technologies?*

Three major factors contributed to the prosperity of the technology imports of Japan. First, because the government feared the economic colonialism by Western countries, it "assisted Japanese industrial corporations in import of foreign technology through locating advanced technology abroad and even in negotiating licensing agreements with foreign licensors. Foreign exchange allocations were also made available on a preferred basis for importing advanced technology" [6]. Second, Japanese companies generally viewed purchasing foreign technology and paying royalties under licensing agreements as much more economical than developing new technology through their own research and development efforts, especially for firms in industries with very short product cycles. Third, the available well-educated and well-trained engineers and technicians of the Japanese corporations could quickly master imported technology and adapt it to the specific requirements of Japan and even develop new technology from these imports [6].

3.2.3. *Policies in indigenous technology development*

Nevertheless, the policy makers (MITI) were fully aware of Japan's excessive dependence on foreign imported technology. The Industrial Technology Agency published two related papers in 1949 and 1950. The Technology White Paper published in 1949 ("The Present Conditions of Industrial Technology in Japan") stressed the importance of technological development. The Research White Paper published in 1950 ("The Present Conditions of Experimental Research in Japan") focused on promoting technological development and on private investment in research and development (R&D). Four measures were listed as specific tasks of technology policy: (1) maintaining a balance in experimental research activities, (2) providing subsidies for experimental research in mining and manufacturing technology, (3) establishing a special corporation to supply needed funds for industrial applications of technology, and (4) developing special tax measures to support private experimental research [18].

To encourage indigenous technology development, one of the powerful policy instruments exercised by the government was the control of technology imports. Imported technology (through technical licensing agreements) was screened and approved or disapproved based on whether it met three criteria: contributing to Japan's international balance of payments, being conducive to the development of key industrial or public utilities, and being necessary for the continuation or renewal of technical licensing agreements relating to key industries or public utilities [18].

3.2.4. *China*

The Chinese government employed and balanced both indigenous development and foreign technology imports. Recognizing that imports of foreign advanced technology was a key factor in its economic growth and technology exports, China initialized a series of reforms to adopt a fairly liberalized trade policy for importing highly sophisticated and advanced technology. China expanded technology imports in essential sectors such as energy, transportation, telecommunication, petroleum, chemicals, raw material, and some high-tech areas such as switchboards, microelectronics, aircraft manufacturing, space technology, and nuclear energy. From 1978 to 1998, China signed 27,875 contracts ($104.97 billion) for technology imports. Just in 1998, 6000 contracts were signed ($6.5 billion) [26].

China's technology export, an indicator for successful indigenous development of technologies, was achieved only in the late 1990s. By the end of 1999, China had exported 9198 technological items to more than 100 countries, with the contractual volume amounting to $28.22 billion. China's technology exports began with the mere transfer of software technology and had progressed to complete sets of equipment, high-tech products and technical services. In 1998, China signed 2500 contracts for technology exports ($6.69 billion) [26].

What has contributed to the rapid growth of high-tech exports? The rapid growth of exports is due to China's policy of "enhancing trade by relying on science and technology" and efforts from government agencies, especially the Ministry of Foreign Trade and Economic Cooperation (MOFTEC). MOFTEC used the strategy of revitalizing trade through S&T, importing foreign technology to develop a wide range of high-tech products and creating enterprises matching international standards and competitiveness. Two other ministries worked jointly with MOFTEC in creating a series of initiatives to promote foreign trade through S&T, the Ministry of Science and Technology and the Ministry of Industry. They placed an emphasis on developing high-tech products for export and upgrading the technology level of traditional exports, especially for sectors such as information technology, biomedicine, consumer electronics, and household electrical appliances [26].

Various departments and government agencies connected with foreign trade also extended full-support to high-tech enterprises, from granting import and export powers, to holding exhibitions abroad, training human resources in foreign trade and marketing abroad, encouraging foreign funding for manufacturing capital, to providing information on high tech products and technologies through established information service centers. To promote China's high-tech products, the government also organized exhibitions of Chinese high-tech products to the international market. For instance, from 1999, International High-tech Achievements Fair has been held in Shenzhen each autumn. Beijing International High-tech Industries week is held in May each year [26].

Some authors [26] emphasized the importance of foreign direct invest (FDI) in creating and promoting export-oriented production because FDI helped to encourage investment in R&D and facilitate the development of intellectual property (IP) law. However, we argue that indigenous technology development efforts made by domestic enterprises are essential to China's technological capability development and the growth of technology exports. All other players, the government, the concerned agencies, R&D, HR, only added to the strength of domestic enterprises performing well in technology exports. A study on domestic firms of China's information industry [27] has proven that innovation capability and self-developed technologies have been the key to Chinese domestic telecom equipment firms' catching up with multinational companies and determined who the leading domestic firms in these industries are.

3.3. Engaging the business sector in R&D development

Another characteristic of Japan and China's development of technological capability is each government's ability to engage both the public and the private sectors.

3.3.1. Japan

As mentioned previously, the Japanese government played a crucial role in developing Japan's technological capability. For example, MITI's actions fell into four main categories and ensured private sector's as well as the public sector's participation. These actions ranged from providing incentives (R&D program, financing), to stimulating R&D activities (R&D consortium), to using regulation to encourage and protect innovation, to facilitating dissemination of the innovation (diffusion, transfer, demonstration, public procurement).

During 1963–1970 [18], MITI developed programs to aid the development of technology in the private sector, including:

- Subsidies for R&D expenditure for important technology.
- Tax incentives for R&D and facilities required for commercialization of new technology.
- Financing for indigenous technology promotion (Japan Development Bank loans).
- Establishing mining and manufacturing technology research associations.

Table 2 listed the means of stimulating R&D activities initiated by the private sector. The activities have a wide range, from direct financing to indirect tax incentives, from R&D on fundamental technology to conditional loans for specific R&D. It also reflected the government's policy in terms of sector priority. For instance, the conditional loans from 1980 focused on energy R&D for oil substitution and new power generation.

A closer look at Japan's manufacturing R&D expenditure further reveals that the business sector has been the driving force for Japan's high R&D expenditure. The manufacturing R&D expenditure increased with an annual rate of 9% (from 227.3 billion yen in 1955 to 7 825.5 billion yen in 1994). Meanwhile, government support has dropped from 10% in 1955 to less than 3% in 1994 of the total funding [28].

3.3.2. China

During the reform era, enterprises have become the driving force for China's technology development. They became the major contributor to national S&T funds and the major spender on national R&D expenditures. For example, while the national S&T funds increased more than six times from 1991 to 2001 (from 42 billion Yuan to 258 billion Yuan), enterprise contribution increased more than ten times during that same period and contributed to more than half (56%) to total S&T funds in 2001. While both government funds and bank loans increased in absolute amounts, they decreased relatively and contributed only 25% and 7% to the total fund (Fig. 4).

R&D covers more specifically innovation creation and has a much narrower definition than S&T. China's R&D expenditure was slightly less than half of the S&T funds (258 billion Yuan) in 2001. Similar to S&T funds, enterprises are the major spenders on R&D. For instance, large and medium enterprises spent 44 billion Yuan in R&D, accounting for

Table 2
Stimulation of R&D initiated by the private sector

Period	Activities
1951-	Financing for Industry's New Technology
1967-	Tax Incentives for Technological Development
1980-	Conditional Loans for Energy R&D (oil substitution)
1981-	Conditional Loans for Energy R&D (new power generation)
1985-	R&D on Fundamental Technology (investment/financing)
1988-	International Joint Research Grant Program
1993-	Conditional Loans for Energy R&D (rational energy use)

Source: The authors summarized from various MITI documents.

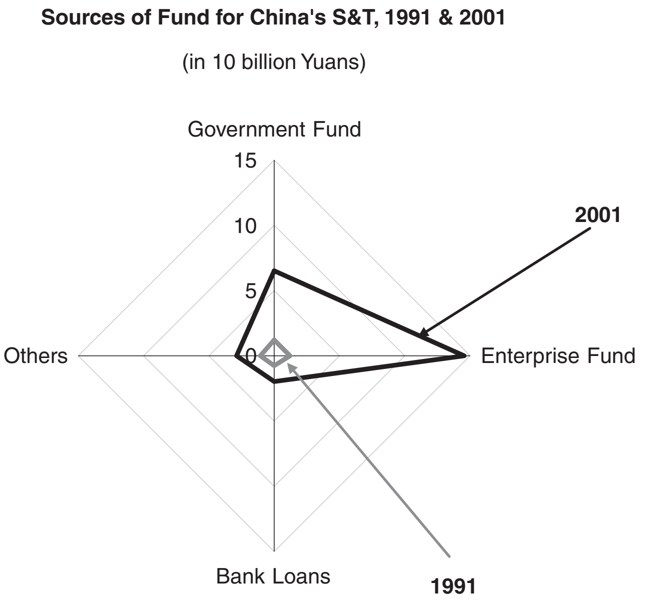

Fig. 4. Source of Fund for China's S&T, 1991 & 2001. *Source*: The authors summarized based on data from China Bureau of Statistics [11, p. 6].

42% of the national R&D expenditure in 2001, increasing from 14 billion Yuan in 1995 (Fig. 5).

4. Policy implications

We have analyzed the economic development of Japan (since 1960) and China (since 1980) in order to assess the role played by technology policies and identify lessons learned that can help policy makers in developing countries make evidence-based decisions about the most appropriate strategies to develop science and technology programs. The key recommendations emerging from our research can be summarized as follows:

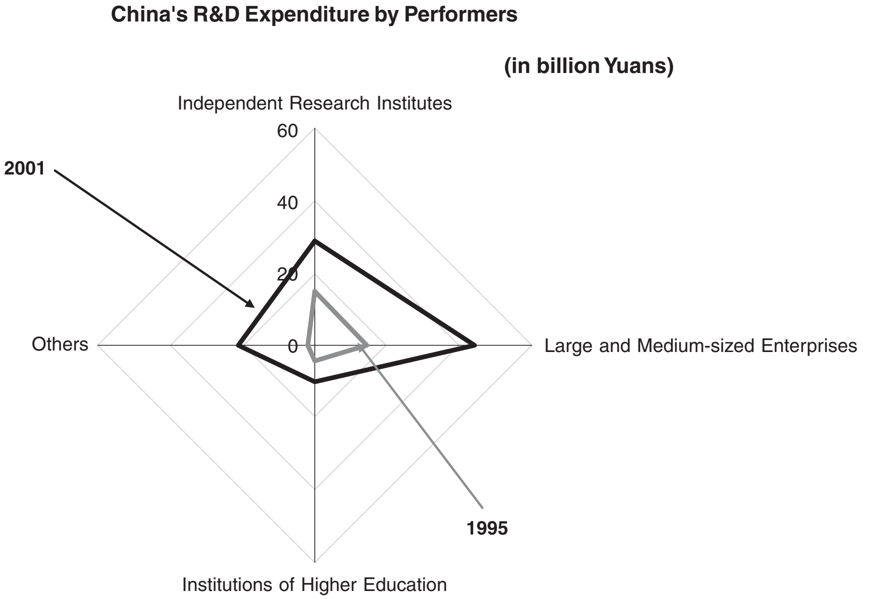

Fig. 5. China’s R&D Expenditure by Performers. *Source*: The authors summarized based on data from China Statistical Yearbook on Science and Technology [11, p. 7, Tables 1–7].

4.1. The role of the Government

Developing countries must be aware that the government plays an inducing role in developing technological capability. Governments provide long-term vision, coordinate different partners, and ensure a healthy domestic environment for creating and using knowledge for socio-economic development. Both the Japanese and Chinese governments played a major role in enhancing their respective countries’ industrial technological capability, which contributed considerably to economic growth. The Japanese government started much earlier than the Chinese government, before the early Meiji period (1868–1890). Its post-World War II involvement through the MITI covers a much larger range of activities, with a specific focus on key sectors during various decades. Japan’s experience also reveals that inappropriate institutional settings can impede innovation. Therefore, government should dynamically adapt institutional settings to facilitate innovation.

The Chinese government started its national innovation system reform in the 1980s. It took the government several tries to find a relatively successful approach to reforming the R&D system. The government also implemented two large-scale distinguished national S&T programs (the 863 Plan and the Torch Program) which aimed to foster high-quality fundamental research and to facilitate the commercialization of technology. The State Council’s “Decision on Accelerating S&T Development” in 1995 boosted the country’s R&D spending, and consequently, technology progress contributed significantly to the nation’s economic growth in the second half of the 1990s.

4.2. Localized solution

Policy makers need to adopt localized solutions that correspond to the country's development stages. As Japan and China's experience illustrates, the process of improving technological capability is a complicated one. Developing countries' governments should consider policy options that fit with their countries' specific socio-economic context. Japan's creative R&D institutions such as R&D consortia are unique and correspond to Japanese culture which forged linkages between various R&D partners. Similarly, the reform of China's national innovation system attempted to change its Soviet-style R&D system. Using the China experience as a case study, it is almost guaranteed that the first step of developing countries' reform will not lead to the success, yet the failure of the earlier attempts can eventually lead to success in the later stages.

4.3. Foreign vs. indigenous technology

To facilitate the development of technological capability, developing countries should encourage both the import of foreign technology and the indigenous development of domestic technology. The import of foreign technology can be a short cut to short-term technological capability improvement. However, a long-term approach should focus on developing capability through building up national human resources, this in turn will increase the country's ability to absorb and redevelop imported foreign technology as well as its ability to develop indigenous technology. Japan benefited greatly from both imported technology and indigenous development. Since the 1960s, MITI focused on promoting indigenous technology development through policy tools such as the control of technology imports. It is well known that Japanese workers are probably the best educated workers in the world. They not only have the skills to absorb imported foreign technology, but also to improve and redevelop them. In China, technology imports and indigenous development go hand in hand, as illustrated by the rise in the number of contracts for both imports and exports of technology. The rise of domestic firms in the information and communication technology (ICT) industry further proves the importance of self-developed technology.

4.4. The role of the private sector

Developing countries' government should engage the business sector in R&D development. Many developing countries have a weak market mechanism and an underdeveloped business or private sector. Developing market mechanisms and promoting indigenous technological capability should be pursued in parallel. Both Japan's and China's experience indicate that the business sector should be a major source of innovation. For instance, Japan's MITI developed programs to aid the development of technology in the private sector and China's reform in the 1980s focused on pushing enterprises to be the driving force of S&T and R&D activities.

5. Conclusion

In this paper, we compared Japan's and China's experience and analyzed how their technology policies contributed to their industrial development and what developing countries can learn from their experience. Numerical analysis proves that technological capability has significantly contributed to Japan's and China's economic growth, especially during the peak growth periods of 1960s to the early 1990s for Japan and from the 1980s onward for China, especially in the second half of the 1990s. A review of the technology policies of both countries highlights the role of government in promoting technological capability, the importance of balancing the import of foreign technology and indigenous development, and the engagement of business/private sector as a major force in improving technological capabilities.

The paper provides several policy recommendations to developing countries. First, developing countries should be aware of the importance of government and its existing policy tools in technology development. Moreover, a country's government needs to adopt localized solutions that correspond to the country's development stage and fits its specific social-economic reality. Further, developing countries should utilize both the import of foreign technology and indigenous development of domestic technology. Finally, the business sector should be a major source of innovation and developing countries' governments need to engage their domestic enterprises in R&D development.

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