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Technological Learning and Technology Mastery by 10 Companies Under the Supervision of Agency for the Management of Strategic Industries (BPIS) in Indonesia Prior to the 1998 Economic Crisis

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ABSTRACT

This study examined technological learning in developing high-tech industry within the state-owned companies under supervision of the Agency for the Management of Strategic Industries (BPIS). This study aimed to investigate the high-tech development through technological learning approach as one method for developing the nation's S&T (Science and Technology) infrastructure. This work was performed through desk research by tracking the available company reports and study results on 10 selected companies under strategic industries in Indonesia from 1989 to 1998. As confirmed by the study results, the history of Indonesian innovation policy, which emphasized on technology-based industrial transformation, was implemented through real, staged process with clear concepts and objectives at an enterprise level. Short-term innovation traps should be avoided for not repeating the innovation break, which had become the primary concern of short-sight's actors in technology politics. The following are two keys of successful technological learning: (i) "Continuous without break", namely the innovation continuity, which should be undertaken even by confronting the crisis situation, has become a requirement for innovative industrialists engaged in innovative economic activities. (ii) Companies could take alternative paths in continuous technological learning to climb the technological ladder by continuously upgrading their R&D and engineering capability in the global competition sphere, because a company cannot survive without building a strong foundation of technological capabilities by establishing an "innovation climate/culture".

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I. INTRODUCTION

Prior to the 1998 economic crisis, Indonesian government implemented an industrial transformation policy based on high-tech application, which was overseen by the State Minister for Research and Technology (KMNRT). At that time, the development of Indonesia's high-tech industry, led by strategic state-owned enterprises, seemed promising to become a vehicle for technology-based industrial transformation. However, the processes were hindered by several drawbacks, such as lack of competitive capabilities, as well as lack of physical and institutional supports. Following the 1998 economic crisis, the position of 10 companies that previously received special treatment by Agency for the Management of Strategic Industries (BPIS) under the coordination of the State Minister for Research and Technology (KMNRT) was reviewed. Then, they subsequently became the state-owned industries without special treatment under the authority of the State Minister for State-Owned Enterprises (MENEG-BUMN).

The Indonesian government took over the task of developing technology-based industries at that time. The collective choice in building nation's technological capability is largely determined by the choice of technology to be developed and choice of key industries to be established. The establishment of key industries as a mainstay for technological development could theoretically be replaced by the new ones only when such industrial technology has already reached a mature stage toward decreasing trends or becoming less adaptable, as it indicating the dynamics of nation's economic development. Following the 1997 Asian economic crisis, policy changes, such as reviewing high-tech choices at strategic state-owned companies in Indonesia, were unavoidable. As a result, the continuity of high-tech development as a driver of long-term economic development was practically ignored during the Reform era.

It is critical to remember that the nation's path of science and technology (S&T) development is a continuous journey in the long term. The fluctuating trajectory of S&T development in one period cannot be separated from the previous eras of S&T development or knowledge accumulation. Akbar and Handayani (2021) documented the advancement of S&T during the colonial era. Boomgaard (2006) discussed the evolution of S&T since the colonial era, as well as the Old and New Order era. Aminullah (2020) wrote about the development of science, technology, and innovation (STI) during the New Order and Reform era. Amir (2004) conducted the specific research on Indonesian high-tech development from the techno-nationalism perspective. To date, however, no research has ever been conducted to investigate high-tech development through technological learning approach as one method for developing the nation's S&T. Therefore, the *objective* of this research is to examine technological learning in the developing high-tech industry prior to the 1998 economic crisis, within the state-owned companies under the supervision of BPIS.

This study was performed through desk research by tracking the available company reports and study results on 10 selected companies under strategic industries in Indonesia from 1989 to 1998. The archives of project on 10 strategic industries was part of the "Technology for Development" related projects in the Asian region (Sharif, 2021). The archives were studied, then were supplemented with relevant scientific references that discussed Indonesian high-tech development from 1989 to 1998. The difference between this study and previous studies is the perspective through which we analysed the controversy issue around BPIS; also we applied a systemic perspective to investigate the technological learning approach at firms level, as explained in the following section.

II. LITERATURE REVIEW AND ANALYTICAL FRAMEWORK

A. Literature Review

According to the direction of technological capability ladder perspective, there are two paths for developing the nation's S&T: (i) R&D governance on STI; and (ii) learning by doing, using, and interacting (DUI), mostly through R&D (Lundvall et al. 2009). R&D governance on STI path is directed downstream from basic research results to commercial innovation, whereas R&D governance on learning through DUI path is directed upstream from innovation to mastery of technology and ends with basic research capabilities. The chosen path cannot be separated from the paradigm used in the development of the nation's technology.

First, developed countries, such as those in Europe and the United States are well known for implementing the STI path, which begins with basic science R&D, then proceed to technological invention and innovation of the commercial products. The spread of commercial products at the local, national, regional, and global levels has become the driving force behind the evolution of developed nations' economic development and prosperity. *Second*, in contrast to the first, the late-comer countries in East Asia (Japan, South Korea, and China) are well known for implementing the learning through DUI path, namely begin with improving innovation (generally through creative imitation), continue with perfecting their research for technological inventions, and end with refining their research skills for basic science discovery. Commercial products that are commercialized locally, nationally, regionally, and globally as a result of continuous improvement have become the driver of economic progress and the welfare of late-comer countries that have managed to catch up with the STI advancement.

Developed countries' S&T development is mostly rooted in a *science culture* that deeply embedded in western society. Meanwhile, the technology innovation efforts in several late-comer's countries are closely related to scientific culture backwardness. They are attempting to catch up by engaging in "continuous" learning in accordance with the learning through DUI path, and have demonstrated success in reaching the end of the learning through DUI path, namely knowledge-based economic development. As a result, it is critical to understand that the late-comer countries' successes are the function of learning to catch up with the latest advancement.

The key of successful learning to catch up is "continuous without break[1]," because if the learning process is "broken off", the knowledge accumulation from the learning outcomes will become obsolete due to the rapid changes and progress of knowledge and S&T. During 1989 to 1998, Indonesia once implemented the learning through DUI path and succeeded in reaching the technological invention stage, but it did not progress to the end stage of the learning through DUI path, namely the discovery of science as the foundation for knowledge-based economic development. In order to explain conceptually how the learning through DUI was implemented in Indonesia, the next section will describe the framework of learning through DUI path called technological learning from the systemic perspective.

B. Analytical Framework

The implementation of continuous technological learning in each country is unique. Japan applies technological learning through continuous improvement by acquiring foreign technology through R&D. Firms can engage in innovation in a variety of ways, ranging from simple to complex, moving from learning by doing, using, and interacting (DUI) to learning by integrating (LI) and porting (LP), then performing R&D in the fields of science, technology, and innovation (STI) (Kodama et al., 2014). In Korea, as it progressed from one stage to the next through the preparation, acquisition, assimilation, and improvement of foreign technologies, the company acquired migratory knowledge to expand its prior knowledge base and proactively constructed crisis as a strategic means to intensify its learning effort (Skiera et al., 1998).

The continuous technological learning efforts in Indonesia appeared similar to Korea, with the difference being that the Korean firm's successfully moved from imitation to innovation by challenge (it even deliberately constructed the crisis), whereas the Indonesian strategic industry was unable to continue with perfecting the R&D sector for technological inventions, and ended up with refinement R&D for basic science discovery

[1] We use the suitable term of "continuous without break" that reflected the reality of temporary break on technological learning in Indonesia just after the 1998 economic crisis, which is different from the term of "technology continuity, discontinuity, and shift" (Engelbrekt et al., 2021) as the patterns of technological development.

after being hit by 1998 economic crisis (Aminullah, 2020).

In the face of an economic crisis, maintaining strategic industry survival was a complex matter, mainly indicated by conflict between public acceptance and industrial efficiency due to the impact of economic crisis (Aminullah, 2017). This conceptual underpinning contends was the complex issues that require proper approach, referred to as a systemic perspective. Hence, we developed an analytical framework, namely technological learning in high-tech companies according to a systemic perspective, as displayed in Figure 1.

The central concept of this analytical framework's is learning through DUI path in the form of double loop subsystems that functions as a self-organizing system. The first loop is the feedback subsystem, and it is connected to the second loop, namely the feed-forward subsystem. DUI's coupling loop is an example of continuous learning for STI development. This continuous learning is fuelled by an accelerated industrial transformation strategy that focuses on the development of targeted strategic industrial technology from downstream stage to upstream stage, referred to as the four stages of technological development, by actually innovating the industrial technology through R&D activities. This strategy's execution is based on the anticipated benefits of industrial technology transformation mechanism, which include (i) forward economic benefits from marketed industrial products (either through government procurement, domestic, or export markets), and (ii) sustainable forward technology capability building that leads to the accelerated transformation process of the four stages of industrial technology development. This self-organizing system will work well as long as the demand-driven innovation improves. However, the economic crisis suddenly interrupted innovation improvement from meeting the demand, also broke continuous leaning. Consequently, the situation has encouraged the high-tech firms to seek alternative paths of technological learning in the Reform era.

III. TECHNOLOGICAL LEARNING AND TECHNOLOGY MASTERY

BPIS implemented technological learning for technology mastery in four stages: (i) mastery of existing technology, (ii) technology integration, (iii) technology development, and (iv) basic

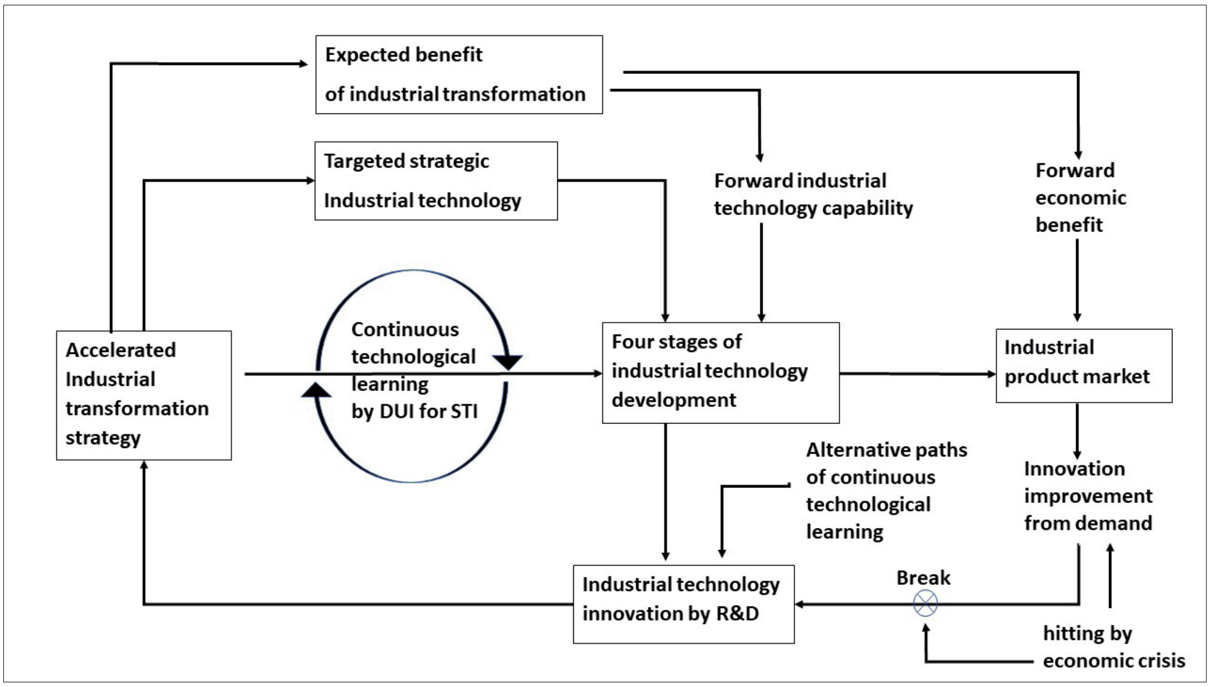

Figure 1. Technological learning in high-tech companies according to a systemic perspective (constructed by Aminullah)

research. The term progressive manufacturing plan (PMP) is used in the implementation of the first stage (technology mastery), which is further divided into four implementation phases, namely (i) Completely Built Unit/Completely Knock Down (CBU/CKD) introduction phase, (ii) assembling phase, (iii) partial manufacturing phase, and (iv) full manufacturing phase. The following description is the level of technological mastery based on tracing the available documentation of scientific research reports on 10 Indonesian companies under strategic industries from 1989 to 1998.

Barata Indonesia

Barata Indonesia based in Gresik, East Java. It was a heavy equipment manufacturer specializing in equipment for the Food, Energy, Water, and Machinery sectors. In the food industry, the company constructed several sugar factories and their components. It also built coal-fired power plants, gas turbine power plants, hydroelectric power plants, and various other kinds of power plants in the energy sector. It was capable of producing the largest Hollow Cone Valve mechanical components in the Water sector in Indonesia. Meanwhile, in the machinery sector, it manufactured fabrication and machine components for a variety of heavy construction industries, including railway equipment and its components, petrochemicals, fertilizers, cement, and others. The company constantly upgraded its production machines, which were operated by skilled workers, despite many of them were only high school graduates. For casting products, it collaborated technically with Nippon Fisher, Japan; Pandrol, Australia; Toyo Menka, Japan; and Kobelko, Japan. Heavy equipment products, such as excavators, were licensed by Kobelko, Japan. Casting corner fittings, bucket teeth, chilled rolls, and other self-developed products were other examples of company's products. Dry land sugar factory equipment also underwent self-development. Product sales nearly quadrupled between 1988 and 1992. Government sectors, such as PLN, BUMN, and BUMNIS accounted for the vast majority of product users. Through technical cooperation with foreign companies in many countries, the company's technological capability level entered stage two, also known as technology integration stage (Pitono et al., 1993a).

Boma Bisma Indra (BBI)

BBI was a construction and heavy equipment company based in Surabaya, East Java, with a focus on Energy Conversion, Machinery Industry, Industrial Facilities and Infrastructure, Agro Industry, Services, and Trade. Its business units include (i) internationally certified industrial equipment machines in thermal power plants, oil refineries, and petrochemical processes; (ii) project management and services, such as geothermal power plant products, agro-industry, tanks; and (iii) diesel engine development under license from "Klockner-Humboldt-Deutz AG (KHD), Germany. The company worked on diesel engine products for multi-license systems from companies like Cummins, Mitsubishi, and Daihatsu. The majority of its skilled workers were high school graduates. Its products were marketed domestically, and several others of them were exported: textile machines components were exported to Switzerland, steel structure components were exported to Yemen, condenser power plants were exported to Egypt, and condenser water boxes were exported to China. The company held licenses for several trademarks of Diesel engines, such as Deutz, Daihatsu, Mitsubishi, Cummins, and Storkwerkspoor. Raw materials for Diesel products and factory equipment were still imported, and advanced information technology still depends on foreign parties. Although its technological mastery was still at stage one (using existing technology), the company already possessed full fabrication capabilities for agricultural machinery and equipment in the nipa sugar and palm oil processing industries, and partial fabrication for diesel engines, engineering, procurement, and construction (EPC) services, and construction services for diesel power plants (PLTD) (Pitono et al., 1993b).

Dahana

Dahana, based in Subang, West Java, was a strategic industry company that provided integrated explosives services to the Oil and Gas, General Mining, and Quarry and Construction sectors. Dahana was a pioneer in the production of explosives used in open pit blasting and geodin explosives used in petroleum exploration. Imports from Europe accounted for 95% of the raw materials used in the production of the two explosives. Until 1992, not all machines and production equipment were automated; some were still operated manually. Production was generally conducted on the order basis, resulting in the annual output of 300,000 kg. The company provided after-sales services in the form of warranty, service engineering, and customer training. Around 17% of company's workforce were expert workers with diploma (D3), undergraduate (S1), and post-graduate (S2) educational background, and another 57% were skilled workers with high school background. The company already had an R&D unit, which was still in its early stages. With an ICI-Australia licensed 'water-based-emulsion' factory and a shaped charge (oil well perforating explosive) factory in collaboration with Oil Tech Singapore, the company continued to enhance its technological mastery. Thus, the company obtained the ISO 9001:1994 and 1998 for quality management systems, as well as awards for the engineering and operation of a 'Bulk emulsion on-site plant' on Karimun Island, Riau Archipelago Province. In 1992, mastery of company's technology was at stage one (use of existing licensed technology) (Surya et al., 1993).

Industri Kereta Api (INKA)

INKA, based in Madiun, East Java, was a railroad facilities manufacturer. It was considered the first integrated railroad components manufacturer in South East Asia. INKA manufactured locomotives, electric diesel rail trains, well wagons, generator carriages, and the Jabodetabek light rail transit system. INKA collaborates with a number of organizations, including Nippon Sharyo, Japan; Hyundai, Korea; and Holec BN, Belgium. INKA manufactured freight cars, passenger trains, and other items, such as containers, and motorcycle trucks. The Indonesian Railroad Company is the company's primary customer. Passenger trains, ballast garbing, flat carriages, and locomotives were among the INKA products that were exported to Malaysia, Singapore, Vietnam, the Philippines, India, and Australia. INKA was Indonesia's only manufacturer of railway facilities. High school graduates accounted for more than 85% of its skilled workforce. INKA conducted several strategic decisions to demonstrate its technological capability, such as (i) assembly of electric multiple units (EMU) and product diversification; (ii) export of freight wagons to Malaysia; production of electric multiple units (EMU) of VVVF; (iii) launch of new Argo Bromo passenger coach; assembly of locomotives (GE Lokindo) to be exported to Philippines; (iv) launch of Argo Bromo orchid passenger coach (leasing scheme); and (v) export of ballast hopper wagon to Thailand. The company's technological capability level was at stage two (technology integration) in 1992, as a result of partnerships with a variety of foreign companies in many countries (Mularsono and Pitono, 1993).

Industri Telekomunikasi Indonesia (INTI)

INTI was a telecommunications company based in Bandung, West Java, with the primary goal of becoming a leader in the telecommunications and information sectors. Central products (such as: Sentral Telepon Digital Indonesia/STDI – Indonesian Digital Telephone Central/IGTC), Terminals (telephones), and Transmission products, as well as Installation and Services, were the main products it manufactured. Suppliers and product quality enhancements were carried out with the assistance of experts/skilled workers and facilities from various domestic companies and institutions, including PT PAL, IPTN, LEN, ITB, KIM-LIPI, TELKOM, Indosat, and TVRI. Siemens, a German company, participated in international collaboration. The manufacture of three Central and Terminal products—STDI products, telephones, and public telephones—had improved as a result of this collaboration. AT&T and NEC (Japan) were the two primary import competitors to Central products (STDI). The four largest telecommunications operators in Indonesia were among INTI's main customers: PT Telekomunikasi Indonesia (Telkom) (92%); PT Indosat (6%); and Private and Ministry of Information(2%). The company only hired domestic workers (no foreign workers) with around 27–29% of them were high school graduates.

Almost all company's products were custom-made. The company sourced its technology from licenses with increased in added value through technology integration for central and terminal products, which were already competitive, as evidenced by a 141% increase in STDI production over the last four years (1989–1992). The company's technological capability was at stage two (technology integration) (Hermawati and Pitono, 1993a).

Industri Pesawat Terbang Nusantara (IPTN)

IPTN was an aircraft and service company based in Bandung, West Java. Fixed-wing aircraft, helicopters, weapons systems, components, and services were all IPTN products. Product types and quality were improved with the assistance of in-house laboratories and workshops, as well as from the collaboration with various global aircraft companies, such as CASA Spain, NDO Japan, NLR Netherlands, Boeing USA, and others. Helicopters and aircraft models, namely NC-212, CN-235, NBO-105, NAS-332, NBEL-412, and N-250, as well as various components, were among the products sold. IPTN had completed phases one, two, and three of technology transformation. The NC 212 aircraft program, NBO-105 helicopters, NSA-330, NAS-332, NBELL-412, and F-16, B-737 components, and B-767 underwent stage one (technology introduction). Stage two (technology integration) was carried out for the CN-235, NC-212 Rain Maker, and NBELL-412 Gunship programs. Stage three (technology development) was carried out on the N-250 program, development of Vertical Composite, CN-235 Fin, and development of the CN-235 platform. At that time, there was no real program for stage four (basic research). In the implementation of stage one, IPTN was obtained licenses from various foreign parties, such as helicopters that were licensed by MBB Germany; Aerospatile, France; Bell Helicopter Textron, USA; and Belgian FZ. In the next stage of technology transfer, technology integration was performed to build self-designed products, namely the development of the N-250 fixed-wing aircraft. The CN-235 was created for the first time in 1986, and 21 CN-235 aircraft were created in 1991. From the license, it took 10 years for IPTN to be able to realize the design stage itself. The orders for IPTN products were not only came from the government and domestic companies, but also from various countries in ASEAN and international parties. The majority of its workforce at that time were skilled workers with high school educational background, majoring in Engineering. IPTN's actual production capacity was around 60% of its production plan based on market demand, especially for domestic market. The technology tools were on par with the state of the art (SOA) of similar companies even though they have not yet reached the SOA status. Overall, IPTN's technological capabilities were comparable to its international competitors at that time (Nasution et al., 1993).

Krakatau Steel (KS)

Krakatau Steel (KS), located in Cilegon, Banten, was Indonesia's largest steel industry and the ASEAN 's largest producer of hot rolled coils (HRC) and cold rolled steel (CRC), as well as the second largest producer of steel wire rods (WR). The company's products have been exported to Japan, the United States, the United Kingdom, ASEAN, China, India, and the Middle East. Its product sales had ever increased by 150% between 1985 and 1989. Product exports increased tenfold during this time period as well. The majority of its workers (80%) were high school graduates that possessed technical skills. The production capacity was approximately 1.9 million tonnes. Labor productivity was 261 tons per worker, which was still below to that was achieved by POSCO company in Korea (600 tons per worker). Collaboration with the University of Wollongong in Australia, APO, and Thyssens helped the company to develop its human resources. Company's progress in technological mastery were shown by (i) President Suharto inaugurated the Slab Steel Plant (Electric Arc Furnace) and Hot Strip Mill factory, as well as Unit II Direct Reduction, and (ii) The start of company's expansion and modernization aimed to increase rough steel production capacity, improve the quality and variety of its steel products, and improve product efficiency. Although the company had improved its technological capabilities owing to technological modernization, the result still was not considered a SOA state because the technology used was still below the SOA standards of global steel industry. This company's technological capability was at stage one (mastery of existing technology, at full manufacturing phase) (Ramanathan, 1993).

LEN Industri

LEN was an electronics and communications company based in Bandung, West Java. Precision mechanics, Ferrite, IC Hybrid, and Quartz Crystal were among the electronic components fully manufactured by LEN. Antennas (Yagi, Dipole, and Parabola), Process Controllers, and Small Earth Stations were all examples of power converters that also produced by LEN. Meanwhile, assembled products that produced by LEN include Avionics Converters, Cards Electronics and Avionics Modules, PLTS units, and Security Electronics. The company's flagship products were TV Transmitters and Hybrid IC components. The entire production process for hybrid components and TV transmitters used imported machines from various foreign parties, particularly Japan, the United States, and Germany. In 1992, only supporting equipment, such as solder and guy wire, was made locally. In 1992, the service businesses offered included Avionics, Control Systems, Defence Electronics, Transmission, and Broadcasting. The company's products were used by Telkom companies (80%), PLN, Pertamina, TV companies, railroad companies, and the defence and security industry. LEN began as the LIPI laboratory and was successfully spinned-off as a strategic company under the supervision of BPIS. High school and junior high school graduates accounted for the majority of workers (73%). The company substituted two imported component products, namely Solar Cell and Hybrid. Company's technology mastery was mostly at stage two (technology integration), which was conducted through collaboration with various domestic companies, such as IPTN, PAL, and INKA. In the field of transmission and broadcasting, it had entered stage three (technology development) (Hermawati and Pitono, 1993b).

PAL Indonesia

PAL Indonesia was a maritime company that provided shipping and maritime services and based in Surabaya, East Java. Warship products, commercial ships and their development, fish ships, tankers, tugboats, and floating docks were among the shipping products it manufactured. PAL enjoyed a leading position in the domestic market. Around 80% of its workforce were high school graduates that had taken special training in engineering. Until the end of 1990, PAL had carried out stage three (technology development) for the Tuna Long Liner 60 GT product, while the other products were at the technology integration stage and partly for stage one in using technology for both partial manufacturing phase, such as Steam turbines, and full manufacturing phase, such as FPB 57 and 28. There were no products at stage four, namely basic research. PAL built partnerships with several small industries for the supply of components and also collaborating with ITS Surabaya, BPPT, and Mitsubishi Heavy Industries, Japan for the exchange of experts and information, as well as for R&D and the design of Maruta Jaya ship programs. In 1992, their technological capabilities, including their ability to innovate, had exceeded the best average in Indonesia (Kusbiantono et al., 1993).

Perindustrian Angkatan Darat (PINDAD)

PINDAD, headquartered in Bandung, West Java, was arms and ammunition manufacturer. Weapons (FNC), ammunition, mortar Filling Plant, Forging, Foundry, and Tool Shop were among the examples of its products. In 1992, several of its products were licensed from third parties. The actual production of FNC was based on the 1984–1994 license. Stage one was marked by the company's technological capability (mastery of technology that already exists in the full manufacturing phase). Arms were sold to the Indonesian Ministry of Defence and Security because the company had full government authorization to manufacture weapons and ammunition. The progressive manufacturing plan (PMP) program had only reached the assembling stage for machine tools, vacuum circuit breaker (VCB), and generators, while Rail Fastening products had reached the partial manufacturing phase. Meanwhile, the development of Deck Machinery was still at the early stages, despite the overall production had increased. The majority of skilled workers (roughly 85%) were high school graduates or the degree below it. To improve its products' quality and variety, the company collaborated with several foreign parties, including IPSEN, Germany; Blasberg, Germany; NOBEL Chemature, Sweden; and GMCO, Netherlands (Fatony et al., 1993).

Overall, Indonesian strategic industries' technological learning achievement are summarized as follows: (i) the majority of companies' technological capabilities were still under the 'State of the Art' condition of similar companies in the world; (ii) technological capabilities of the entire companies were still at the best level in Indonesia, except for the IPTN aircraft's technology mastery, which had approached the foreign competitors in its sector.

IV. ANALYSIS

A. Strategic Choice

In each country, the choice of high-tech to be developed is based on strategic reasoning and criteria, which are argued by the government to justify the nation's choice at the time. B. J. Habibie, Indonesia's Minister of Research and Technology from 1978 to 1998, devised a strategy for scientific and technological development (Gammeltof & Aminullah, 2006). During the 1980s, Indonesia defined two strategic reasons for developing its high-tech choice: (i) the concept of unification in the Indonesian archipelago, and (ii) the concept of national development take-off. Under a variety of political, economic, social, and cultural realities, archipelago unification became the basis of political and economic unity purposes. Based on the concept of archipelago, Indonesia required uniqueness in its transportation (land, sea, and air), as well as a sophisticated communication system. Indonesia implemented the concept of these two strategic reasons by operating 10 companies for technology-based industrial transformation (as explained in the previous section).

The government's intervention strategy in developing high-tech industries comprises the following five paths: (i) commitment to education and training in various fields of science and expertise through extensive fellowship programs, both locally and abroad, to augment the supply of high quality S&T personnel (Alam, 1995); (ii) the development of technological capability to address the nation's real problems and future needs in connection with meeting national strategic needs[2]; (iii) learning through DUI to manage technology transfer, adaptation, and indigenous technology development by establishing the 10 strategic companies[3]; (iv) accelerating indigenous technology development by implementing four stages of industrial transformation from downstream to upstream, namely utilizing existing technology to generate added value, integrating existing technology with new knowledge and creativity, improving imported technology with applied R&D activities, and improving the already developed technology with achievement in basic R&D activities, and; (v) developing global competitiveness, as measured by export performance in addition to the ability to meet domestic demand.

The successful transformation in all four stages was demonstrated by the production of aircraft at IPTN, starting from assembling of various small planes and helicopters, followed by integration of previous knowledge gained in assembling for the production of airplane (with double engines) designed in cooperation with CASA (air-tech) in 1984, followed by improvement of aircraft technology through R&D activities to build the aircraft. The final stage was marked by full production of a jet aircraft. However, termination of production process was unavoidable, because IPTN was hit by the

[2] In this case, the development of the telecommunication system of satellites in Indonesia as of 1976 could be mentioned as the answer to difficulties and slowness of communication in Indonesian archipelago. Simultaneously, satellites were built with principal aim to enhance Indonesia's capability in providing information service and open up many opportunities in facing the era of modern electronics and communication technology.

[3] These 10 strategic state-owned enterprises were IPTN, now DI (aircrafts); PAL (shipbuilding); INKA (railroad wagons); LEN (electronics); INTI (telecommunication); PINDAD (light weapons and ammunition); DAHANA (explosives); BBI (engines and machinery); BARATA (heavy equipment and construction material); and KRAKATAU (steel). For details, see section 3.

1998 economic crisis. In general, the products of strategic industries to meet domestic demand as import substitution had been hampered by the failure of Indonesian high-tech products to penetrate the export market. This occurred as a result of weak marketing and insufficient support from the private sector for ideas of "the Indonesian Incorporated" to spread through the international market by utilizing effective public and private cooperation to enforce national industrial development.

B. Continuous Technological Learning

The paths of S&T development in a country continually shifts along with the time and the dynamics of global economic development. The dynamics of paths shifts are described as follows: (i) *engagement in basic research* (in 1950s) to send humans to the moon, especially by the US (Zachary, 1997); (ii) *technology transfer* (in 1960s) among countries, especially from developed countries to developing countries (Chatterji, 1990); (iii) *appropriate technology* (in 1970s) with adaptation of western technology to local needs, including to develop indigenous technology, even high-tech for Indonesia (Bhalla, 1979); (iv) *continuous technological learning through DUI* (in 1990s) by late-comer' countries (Lall, 1996); (v) *national innovation system* (from 1980s to 1990s) by explaining interaction of all actors involved in innovation (Nelson, 1993); and (vi) *transformative innovation system* (from 2000 to the present) by directing interaction of all actors involved in innovation for transformation to sustainable development (Schot & Steinmueller, 2018).

The application of the continuous learning through DUI path to develop the nation's S&T has been successful in many developing countries in East Asia, as well as in Latin America. There is no single learning type of DUI path that applies evenly for all countries; instead, it is usually adapted specifically to the social, economic, and cultural conditions of each country. Unfortunately, despite the fact that Indonesia was ever quite successful in developing the nation's technological capabilities by applying continuous learning through DUI path in companies under the governance of BPIS, such technological capability building was interrupted by the 1998 economic crisis. The interruption was then followed by the dissolution of the status of BPIS. As a result, the continuity of DUI's technological learning was also halted. If Indonesia consistently strived in building its technological capability during a crisis, it would likely catch up with Korea[4], which did so by viewing crisis as a strategic means of intensifying its learning effort (Skiera et al., 1998).

Despite the fact that BPIS was a thing of the past during the New Order era, the company still exists nowadays and operates under Reform era. Companies that are late-comer in high-tech capabilities should take alternative paths to continuously pursue technological learning. Late-comer firms usually face two disadvantages: (i) they are technologically being left behind, and (ii) they lack research, development, and engineering capabilities. Therefore, Huang and Intarakumnerd (2019) suggested four different types of technological learning paths to overcome these two disadvantages: (i) act as an independent supplier that sell innovative products based on in-house R&D to any customer in open markets; (ii) start-up can be an alternative strategy in emerging high-tech industries by recruiting and training high-talent engineers; (iii) act as a path breaker to break the difficult of climbing up the technological ladder by developing design and engineering capabilities for technology diversification; and (iv) specialize in high-valued added activities by enhancing capabilities in advanced engineering, design, research and development, branding, and marketing.

Huang and Intarakumnerd (2019) demonstrated the importance of various supports to ensure the successful policy instruments in high-tech development. For instance, R&D subsidies or competitive grants from government, which can be utilized to develop new products or sys-

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[4] Innovation discontinuity in developing technological capabilities has resulted in Indonesia's failing to catch up with Korea. At symposium on Industrial Technology Innovation Management for Sustainable Economic Development, July 8, 2021 in P2KMI –LIPI, Prof. Nawaz Sharif said: "In the 1990s, the technological gap between Indonesia and Korea was 20 years; now, Indonesia is 40 years behind."

tems, are important for firms' product innovation and market diversification beyond their existing business operation. Subsidies can assist firms in lowering the costs and risks associated with developing new products that had not yet been tested in the market. Another source of assistance may come from collaboration with universities and public research institutes in developing new products and/or systems outside of firms' existing original equipment manufacturer (OEM) arrangements. During the collaboration process, these companies can acquire new design skill and R&D capabilities. It is important note that the instrument of R&D subsidy through funding agencies is important for financing and managing R&D projects in Korea. Several ministries have established their own funding agencies for financing and managing their R&D projects (OECD, 2009).

Therefore, the important lesson that can be drawn from the above discussion regarding the Indonesian high-tech development that has almost been ignored are summarized as follows: (i) The key to successful technological learning is "continuous without break" and the companies that are still late-comer in high-tech firms could take alternative paths in continuous technological learning; (ii) A company cannot survive without building a strong foundation of technological capabilities, but the capabilities can often be duplicated by competitors, thus it is difficult for them to continue to provide a competitive advantage. Therefore, a company must strive continuously to innovate by acquiring and utilizing new technology assets (Smith & Sharif, 2007), and (iii) Learning from South Korean's success in fostering technology innovation induced by sustainable economic growth strategy, it is imperative for Indonesia to pay special attention to the crucial role of creating an "innovation climate/culture" as necessary foundation to support various technology development efforts (Sharif, 2020).

V. CONCLUSION

Prior to the 1998 economic crisis, the innovation policy in Indonesia, which emphasized on technology-based industrial transformation, was implemented through real, staged process with clear concepts and objectives at strategic industries. Short-term innovation traps should be avoided for not repeating innovation break, which has become the primary concern of short-sight's actors in technology politics. The following are two keys of successful technological learning: (i) "Continuous without break", namely the innovation continuity, which should be undertaken even by confronting the crisis situation, has also become a requirement for innovative industrialists engaged in innovative economic activities. (ii) Companies must take alternative paths in continuous technological learning to climb the technological ladder by continuously upgrading their R&D and engineering capabilities in the global competition sphere, because a company cannot survive without building a strong foundation of technological capabilities by establishing an "innovation climate/culture".

Finally, after the 1998 economic crisis, the 10 companies under strategic industries were coordinated under the governance of MENEG-BUMN. That actually still hinder the process of continuous learning without break, as it caused Indonesian technological development to be even less competitive to operate in today's technology-driven global sphere, and continued to make Indonesian high-tech industries still much dependent on imported technologies.

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