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The Making of East Asia's Electronics Champions

La creación de campeones de la industria electrónica en Asia oriental

Reda Cherif
ACherif@imf.org
International Monetary Fund, USA
Bennett Institute for Public Policy,
University of Cambridge

Fuad Hasanov
FHasanov@imf.org
International Monetary Fund, USA
Georgetown University, USA
Bennett Institute for Public Policy,
University of Cambridge

Gary Xie[1]
garyxie@pku.edu.cn
Peking University

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Abstract

Sustained and high growth in East Asia was achieved by developing sophisticated export sectors, especially in electronics, spearheaded by national "champions." Using the experience of four major East Asian semiconductor firms, we argue that four ingredients of state-firm cooperation were instrumental in their success—ambition, autonomy, accountability, and adaptability (4A). This state-firm interaction involved ambitious goals and policies of the state combined with firms' operational autonomy, strict accountability for the support received, and adaptability to the changing environment. In addition, international and domestic competition, collaboration with multinationals

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and research consortiums, and own innovation pushed firms toward the technological frontier.

Keywords: Industrial policy, innovation, technology, semiconductors, East Asia.

RESUMEN

En Asia oriental se logró un crecimiento sostenido y elevado mediante el desarrollo de sofisticados sectores de exportación, especialmente en electrónica, encabezados por "campeones" nacionales. Utilizando la experiencia de cuatro importantes empresas de semiconductores de Asia oriental, argumentamos que cuatro ingredientes de la cooperación entre empresas y Estado fueron fundamentales para su éxito: ambición, autonomía, rendición de cuentas y adaptabilidad. Esta interacción entre el Estado y la empresa implicó ambiciosos objetivos y políticas por parte del estado, combinados con la autonomía operativa de las empresas, una estricta rendición de cuentas por el apoyo recibido y la adaptabilidad al entorno cambiante. Además, la competencia nacional e internacional, la colaboración con multinacionales y consorcios de investigación y la innovación propia empujaron a las empresas hacia la frontera tecnológica.

Palabras clave: Política industrial, innovación, tecnología, semiconductores, Asia oriental.

JEL Classification / Clasificación JEL: O14, O25, O38, O53.

1. Introduction

Many argue that the role of the state in developing new sophisticated sectors to spur sustained growth is paramount (see Cherif and Hasanov, 2019). One approach for the state is to focus solely on resolving "government failures." The bottlenecks stemming from the government's inefficiencies are cleared to create an enabling business environment, in which the state provides standard public goods like infrastructure and education while leaving the rest to private firms. Structural or market liberalization reforms would unleash the entrepreneurial spirit and allow firms to decide which sectors to enter and which profit opportunities to pursue. Although it is important not to have an overbearing state (e.g., price controls, licenses, export taxes, and crippling regulation), it is also imperative to correct "market failures," which, even in an enabling environment, would still preclude firms from entering sophisticated sectors. Market failures typically result from various externalities such as coordination, learning-by-doing, and short-termism. This approach would call for an industrial policy to tackle these market failures, creating favorable conditions for firm entry and growth in sectors that are conducive to spillovers and productivity gains. The state may lead by providing various types of support and incentives in strategic sectors. But ultimately firms themselves would have to produce a prodigious effort, innovating and navigating in a fiercely competitive international environment. In other words, success would depend critically on the type of state-firm interaction at play.

The rise of the semiconductor champions in East Asia is a good illustration of successful state-firm interactions in a strategic sector. Samsung Electronics in Korea, TSMC in Taiwan Province of China, Hitachi in Japan, and CSM in Singapore became major players in the world electronics market despite the limited prior experience in this technology. Their stories are instructive about the type of state-firm collaboration that led to success. Ambitious goals set by the state and support policies combined with firms' operational autonomy, strict accountability for the support received, and adaptability to the changing environment, were instrumental to the success of these firms. International and domestic competition, collaboration with multinationals and research consortiums, and own innovation pushed firms toward reaching the technological frontier swiftly. The models studied vary from private conglomerates diversifying their operations in the electronics industry (Hitachi and Samsung) to the initially state driven spin-off (TSMC) and the state-owned enterprise (CSM). The level of success ranges from TSMC that became the global leader in semiconductor manufacturing by 2020 to CSM that was sold in the late 2000s after a period of decline. The different experiences bring up important lessons as to scaling up and innovating to compete on the world market in advanced technologies.

Although there are rich studies from the state or the firm perspectives about industrial policy, relatively few studies have discussed the interaction between the firms' profit-driven behavior and the key planning institutions of the state. This paper seeks to further contribute to bridging the two approaches by examining how firms react to policy and the state's incentive structure as well as interact with the bureaucracy of the industrial planners. The paper adapts the 4A framework—ambition, autonomy, accountability, and adaptability—of Cherif, Hasanov and Xie (forthcoming), which explores the features of the institutional setup of planning agencies in terms of 4As that contributed to their success (Table 1). These four features summarize well the key aspects of the growth of the semiconductor industry in East Asia.

Table 1: State-Firm cooperation through the 4As

Features	Institutional Considerations	Interaction Between the State and the Firm
Ambition	Medium- and long-term goals and policies to leapfrog into sophisticated technologies	· How do firms respond to government set goals and policies? · To what extent were the government goals and policies important in driving firm decisions?
Autonomy	Operational independence	· Did the state exercise too much control in day-to-day operations? · How did firms deal with political interference?
Accountability	Independence from interest capture and incentive to achieve goals	· To what extent did firms participate in corrupt activities? · How were firms held accountable for government support received?
Adaptability	Adaptation to changing circumstances	· How did firms respond to changing domestic and international circumstances? · How did firms respond to the state's changing objectives?

The structure of the paper is as follows: Section 2 provides a brief review of existing work on industrial policy and the state's relationship with firms. Sections 3-6 examine each component of the 4A framework in turn: ambition (section 3), adaptability (section 4), autonomy (section 5), and accountability (section 6). Section 7 concludes and discusses policy implications.

2. Industrial Policy and the Firm

The case for industrial policy is strong in developing countries that need to mobilize their limited resources to diversify their tradable sector and move towards an export-oriented economy. State intervention can address economic inefficiencies and support firm growth (Becker, 1997 and Jha and Chaloupka, 2000). Looking at development patterns in East Asia, Amsden (1989), Wade (1990), Chang (2002), and Cherif and Hasanov (2019) find that government industry-targeted policy played an essential role in leapfrogging to the technological frontier at an early stage of development. Freund (2016) finds that industrial policy accelerated the development in agrarian-based societies by concentrating resources into industrialization. Lin (2012) advocates for a facilitating state that identifies and develops industries around its comparative advantages to drive technological innovation. In low-income countries, Benhassine and Raballand (2009) find that it is in these countries that industrial policy is most needed although the conditions for success are not always favorable. Even in advanced economies, Mazzucato (2013) shows that states like Japan and the US have traditionally played a major role in driving innovation and growth. An increasing number of papers recognizes industrial policy as a positive force for industrial upgrading. However, there is no clear blueprint as to the institutional set up needed for policy effectiveness.

The existing literature points to three major characteristics of successful industrial policy. First, the state's mindset and organization matter as they would influence the resulting state-firm interaction. Chang (1993) points out to the important role of long-term dynamic mindset and policies to promote structural changes in Korea's development path. Wade (1990) emphasizes the "developmental state" mindset as well. Cherif, Hasanov, and Xie (forthcoming) examine development planning agencies in South Korea, Japan, Singapore, and Taiwan Province of China, and find that planning agencies across these countries have common features in their (i) ambition, (ii) autonomy, (iii) accountability, and (iv) adaptability. This 4A framework shared across planning institutions in these economies also point to certain patterns in institutional arrangements that help achieve technological upgrade and export promotion while ensuring accountability.

Second, coordination and experimentation are key elements to ensure policies support firms while minimizing distortive effects on the market. Hausmann *et al*. (2008) find that instead of focusing on the "right" set of policies, governments should understand industrial policy as identifying the country's comparative advantage. Harrison and Rodrīguez-Clare (2010) and Wade (2012) observe that soft government intervention, such as public industrial research institutes or export promotion agencies, instead of direct distortions such as subsidies can help address coordination problems in industrial clusters at their early stages of development. The principles of benchmarking, monitoring, and experimentation should drive industrial policy setting.

Third, a push for international and domestic competition helps ensure accountability. Amsden (1994) stresses the importance of the "reciprocal principle," where businesses should not receive state support for free without monitorable performance standard in return. Wade (1990) proposes a comprehensive set of ten principles explaining the success in "governing the market," including the drive to export using different state interventions and an emphasis on locally produced high-quality inputs for both domestic and foreign exporters. Rodrik (2008) suggests three key design attributes for industrial policy, which are embeddedness, carrots-and-sticks, and accountability. Aghion et al. (2015) emphasize promoting competition when setting sectoral policies. Cherif and Hasanov (2019) propose the Technology and Innovation Policy (TIP) framework, which identifies three key principles: (i) state support for domestic producers in sophisticated industries, beyond the initial comparative advantage; (ii) export orientation; and (iii) the pursuit of fierce competition with strict accountability.

Finally, as the interaction between firms and the state is paramount, how this relationship evolves with the changing environment may determine success or failure. It is often observed that there is no agreed upon definition of industrial policy, which makes debating its effectiveness a slippery exercise. However, it is useful to distinguish "versions" or interpretations of it. The version in fashion in many developing countries until the early 1980s focused on import substitution, with relatively little attention to the firm, and more important, to exports or commercial viability. In contrast, in the Asian miracles, or in its current form in advanced countries, firms were at the heart of policies, which contributed to the success of these policies. For instance, Katz (2000) suggests a micro-macro coordination to help insulate firms from structural reform pressures. Macro instruments and meso organizations, such as planning agencies, interact with micro firms to protect them from volatile prices and exchange rates. Government needs to shield companies moving up the technological ladder from external shocks. Matthew (2006) finds that latecomer and newcomer firms in Asia-Pacific region were able to develop due to their ability to adapt to the internationalization or globalization challenge. Lee and Slater (2007) take a different approach and argue that firms lead their country's economic development through an entrepreneurial commitment to upgrade their technological frontier, rather than their country's level of development automatically leading to firms' success. This view seems to imply that firms succeed despite, rather than because of, the state's industrial policy.

Building an environment for success so that young and small firms could grow into "national champions" or "superstar" firms capable of operating and competing on international markets is important for development. Freund (2016) finds that a small number of privately owned superstar firms often support rapid economic growth better than either broad-based growth across most firms or the rise of state-owned firms. Drawing from the example of billionaire tycoons in emerging economies like China, India, South Korea, and Mexico, she finds that firms are more efficient at driving economic development through spillover-linkage effects. Dunning (1981, 1986) proposes five stages of firm development in his Investment Development Path Theory: (1) non-existent inward and outward FDI; (2) inward FDI rises but domestic firms do not have ownership advantage; (3) firms develop ownership advantage (advantage is more firm-specific instead of country-specific), become competitive domestically, and there is more outward FDI; (4) firm ownership advantage comes from managing geographically dispersed assets and firms are internationally competitive; and (5) high inward and outward FDI, corresponding to mature markets. As firms graduate from one development stage to the next, their relationship with the state also evolves as more mature firms prefer more institutionalized relationship that decreases transaction costs from political interference.

Ultimately, while the existing literature points to different features of industrial policy, they converge to some underlying principles of state-firm interaction. This paper contributes to the ongoing discussion on industrial policy by showing that there are salient patterns in the formation and development of champions in electronics in Asia. These patterns point to the 4A framework of ambition, autonomy, accountability, and adaptability observed for state agencies driving development efforts. In other words, we find a mirror image between the private and public sector along these features. The proposed 4A framework allows for a cross-country comparison of state-firm relationships. A study of the theoretical foundations of this framework would be useful albeit beyond the scope of this paper.

The resulting analysis shows the different ways that the state can promote firm innovation and industrial upgrading. Governments need to set the right incentives to encourage firm competition, promote exports, ensure accountability of the bureaucracy, and adapt these policies based on feedback from monitoring channels. Firms too need to be accountable for the support received and adapt not only to the changing state's incentives but also to evolving market trends and globalization.

3. East Asia's Silicon dreams: Ambitious state goals and policies for ambitious firms

The state played the leading role in setting ambitious goals and policies to develop the semiconductor industry in East Asia. The state's ambition was further backed by concrete policies. It is this combination of the state's ambitious goals and policies that jumpstarted the industry. However, industrial policy of the state required a counterpart to make the initial effort into a sustained success. This counterpart was firms, mostly private or run on a market-based basis, that responded to state incentives by organizing, learning, innovating, producing, and exporting. Both new and existing firms were encouraged to enter this sophisticated industry, at the frontier of technology at the time. The state-market collaboration was instrumental in turning ambition into sustainable and overall, extremely profitable firms.

In Korea, the government's ambition played a crucial role in guiding and supporting Samsung's development. The Five-Year Plans, set by the Economic Planning Bureau (EPB), were the primary vehicles through which the government helped coordinate its development ambitions (see Appendix). The very first Plan (1962–1966) started reorienting the economy from agriculture to manufacturing and export-led growth. The strategy was articulated around providing incentives (initially even coercion) and support to existing family conglomerates such as Samsung to enter more sophisticated industries. These conglomerates were traditionally focused on trading and construction, and many of their engineering, heavy industry, and electronics units were established in the late 1960s-mid-1970s under the impulse of the state. Samsung especially benefited from preferential treatment under Korea's Third Five-Year Plan (1972–1976), which mobilized the country's resources for Heavy and Chemical Industry (HCI) drive. The Plan listed five strategic industries that the government heavily subsidized, including through foreign borrowings: electronics, shipbuilding, machinery, petrochemicals, and non-ferrous metals (Rasiah, 2013). The Fifth Five-Year Plan (1982–1986) with a focus on technology-driven products and the 1983 semiconductor promotion law, further supported the push toward the technological frontier.

Government support came mostly in three forms. First, the exchange rate was kept stable and competitive. Throughout the 1970s, despite relatively high inflation rate, real effective exchange rate remained stable. Second, the government provided low-interest loans to chaebols such as Samsung to develop its Semiconductor unit. Chang (2006) estimates that the real interest rate of government export loans to chaebols was around negative 12.5 percent compared to the market real rate of 24 percent in the first few years of Samsung Semiconductor's operations (1975–1979). Lastly, the Korean government indirectly subsidized Samsung and other chaebols' development by paying for research costs and technical training. The government invested heavily in universities and provided research subsidies to chaebols. Overall, Korea's total research investment tripled between 1976–1980 (MOST, 1985). The Korean state also actively recruited the Korean expatriate community in Silicon Valley, encouraging them to bring back their technological as well as managerial knowledge (Kim, 1997).

Strong government mobilization of financial and non-financial resources throughout the 1970s and 1980s helped ensure Samsung's rise. Samsung expanded rapidly after the 1972 HCI Drive. Out of the five sectors the HCI targeted, the firm was especially involved in the first four industries, shipbuilding, petrochemicals, electronics, and machinery, and the major success was achieved in electronics. Accumulating industry's technological know-how by supplying low-cost electronic parts to major Japanese and American manufacturers in the 1970s, Samsung Electronics started aggressively entering the semiconductor industry in the 1980s to reach quickly the technological frontier. With the government support, in the mid-1980s, it weathered the market oversupply and price drops and kept investing in capacity (Kim, 1996). By the early 1990s, Samsung reached more than 10 percent share of the world market in DRAM (Dynamic Random Access Memory), and semiconductor exports became the largest export of Korea (Kim, 1997).

In Taiwan Province of China, government ambitions have been instrumental in the founding of the semiconductor industry, and TSMC in particular, when the private sector was unwilling to do so. In the 1970s, the government made the semiconductor and electronics industry a top priority in its economic development while technological upgrading became a major policy goal of the administration (Ouyang, 2006). However, the market was skeptical about government efforts. Even when TSMC was formed, local private investors were unwilling to participate because of risk-aversion and pessimistic views about the local industry's future (Meaney, 1994). The Ministry of Economic Affairs even had to threaten reluctant investors with auditing taxes, stopping permits, and withholding government contracts and loans to force them to invest in TSMC (Wade, 1990). The government's ambition created a market and helped solve coordination problems between the government and firms.

Specifically, in 1973, the Industrial Technology Research Institution (ITRI), a state-funded industrial research institution aiming to acquire technologies to transform the economy from labor-intensive into innovation-driven, was established (see Cherif and Hasanov, 2019b for an overview). ITRI negotiated technology transfer with foreign companies, recruited talents from abroad, especially from expatriates in Silicon Valley and graduates from top American engineering schools, and spun-off companies by transferring technology, personnel, and even manufacturing facilities to them. These companies would then compete in the market with other private firms, while ITRI retained equity shares (Meaney, 1994).

Like many other major technology companies, TSMC was a spinoff from the ITRI and many of its founding staff were government employees of ITRI before being transferred to TSMC (Ouyang, 2006). When TSMC was founded in 1987, ITRI transferred around 100 engineers it had trained in its Very Large-Scale Integration (VLSI) circuit project as well as a manufacturing plan to TSMC. Thanks to this government support in talent and equipment, TSMC was able to start-off quickly and become competitive on the international stage soon after its founding. By 1988, TSMC's production technology was only nine months behind that of Intel and Texas Instruments, making it one of the most advanced semiconductor foundries in the world just one year after its founding (Jan and Chen, 2006). By the late 1990s, a decade after being founded, TSMC already accounted for almost 40 percent of the world's foundry market (Hsieh et al., 2002).

In Japan too, government ambition played a crucial role in Hitachi's entry into the semiconductor industry. When the Japanese government decided to promote the semiconductor industry in 1975, Japan was in an economic recession after the 1973 oil shock, with an 18 percent inflation rate. Many corporations were unwilling to invest in new industries. The Ministry of International Trade and Industry (MITI) was instrumental in promoting the industry. It provided the financial incentives for companies to transition from a heavy industry-driven economy to a more technology-driven economy (Callon, 1995).

In addition, during 1976–1979, it led a research consortium of five companies, including famous Japanese conglomerates, Hitachi, NEC, Fujitsu, Toshiba, and Mitsubishi, to develop the semiconductor industry. The entire consortium pledged to invest 74 billion JPY (288 million USD), with MITI contributing 60 percent of the total research investment, to develop the VLSI technology to catch up with the semiconductor industry in the US (Callon, 1995). Other than research subsidies, MITI provided an organizational framework, gave access to its in-house research center, the Electro-Technical Laboratory, and set the research agenda. The research spending also built a research and manufacturing infrastructure that helped the industry continue to develop.

The consortium was successful in catching up with the US semiconductor technology. At the start of the program, Japan imported 70-80 percent of its semiconductor production equipment from the US. However, by 1980, it only imported around 50 percent of its equipment from abroad, with domestic Japanese firms able to provide quality alternatives (Sakabibara, 1983). The success, according to Callon (1995), was mostly due to the size and effectiveness of subsidies than the cooperation of multiple companies. The collaboration would have entailed sharing technology and pooling research personnel among the companies while MITI largely provided research funding support for these joint projects.

Although the incentives for companies to share their intellectural property were minimal as they were often competitors, there were still substantial benefits to participation. Most of the research breakthroughs were made in private company labs with MITI funds rather than in MITI joint labs. The vast majority of patents were filed by one company (59 percent by a single applicant and 25 percent by a few applicants from the same company). Nonetheless, 16 percent of patents filed were from joint inventions by different companies (Tarui, 1980), and the research consortium did provide a platform to coordinate among companies. The VLSI Research Consortium applied for more than 1,000 manufacturing patents in silicon crystallization, wafer-processing, device technology, designing, and electron beam lithography (Kato, 1988). In the span of just three years, Hitachi has gained the technology to compete with major American semiconductor manufacturers such as IBM. Ironically, IBM requested MITI to disclose these patents to level the playing field, with which MITI reluctantly complied in March 1978 (Sato, 2001).

Singapore's Economic Development Board (EDB) has initially pursued a strategy to attract semiconductor multinationals (MNCs). Since 1969, many semiconductor MNCs had set up their production facilities in Singapore, and by 1980s, the city-state had become a major semiconductor manufacturing hub (Matthews, 1999 and Rasiah and Shan, 2016). Although MNCs came for the skilled labor force, good business environment, and Singapore's geographic location in the Asia-Pacific, the EDB further supported MNCs with favorable policies including tax breaks, free labor market, and technology grants (Matthews, 1999).

While the EDB continued its strategy of attracting MNCs for investment, in mid-1980s, it started focusing more on leveraging MNCs for local industrial upgrading. After the 1985 recession, Singapore's first since independence (National Library of Singapore, 2014), the EDB realized that Singapore had been too reliant on MNCs and vulnerable to economic slowdowns in advanced economies. The agency urged MNCs to increase their production and create linkages with local firms in return for R&D grants and government equity in high tech firms. Throughout the 1990s, the EDB continued its policy of enticing semiconductor MNCs to broaden their activities and attract all parts of the semiconductor process to have an integrated industry. Domestic firms started participating in an integrated value chain beyond production.

Chartered Semiconductor Manufacturing (CSM) was an outcome of the effort to build linkages with MNCs. CSM was established as a manufacturing firm after the state-owned Singapore Technology Group (STG) acquired a technology license and bought out the shares from the US-based Sierra Semiconductor. While CSM was beneficially held by Temasek Holdings, an investment company owned by Singapore's government, it was allowed to operate independently and on market-based incentives (e.g., compensation and management). The ambition of the Singaporean government to build a strong domestic base helped create a favorable environment for firms like CSM to excel through technology transfers, R&D grants, MNC networks, and an integrated value chain.

4. The State at an arm's length: Autonomy vs. influence

In the state-market collaboration, insulating firms from undue political influence and providing autonomy were instrumental. The role of specific institutions spearheading industry development such as MITI in Japan and EDB in Singapore proved helpful in minimizing political interference from other government agencies. In other words, the existence of overarching technocratic development institutions enjoying a fair amount of autonomy themselves ensured that firms would in turn be protected from undue interference. Close ties with domestic private investors and foreign MNCs and ownership stakes further solidified the healthy relationship between the state and the firm. The arm's length approach of the state gave firms autonomy in their operations helping them reach the ambitious goals set by the state.

In the early days of Korea's development, the social contract between Samsung and the executive gave autonomy to the firm against political influence in exchange for helping the state pursue economic development. Traditionally, Samsung maintained its political autonomy by aligning itself with the executive. Under President Park Chung-Hee's tenure, Samsung and other chaebols had personal relationships with President Park and had monthly meetings with him. Park also protected Samsung from additional political interference from other members of the executive or the legislative branches. In return, the chaebols had to align its goals with the country's economic development and help the state execute its Five-Year Plans, including entry into new and risky sophisticated sectors without prior experience.

However, as Korea entered into a period of democratic transition in the late 1980s, the traditional patronage system with the President weakened, forcing Samsung to pursue transparency within the organization, reduce the hierarchical structure, and adopt more meritocratic policies. Since Korean presidents under the Sixth Republic (1988–present) were only allowed to serve a single five-year term, without the possibility of re-election, Samsung needed to spend more efforts to maintain political relations with new executives and work with different players within different government branches. In addition, while the Korean government strongly supported the business of Samsung and other chaebols in the 1970s, by the late 1980s, thanks to their international success, the chaebols no longer required large state financing and assistance. Because of the chaebols' market size, the government became concerned with excessive industrial capacity of the chaebols and antitrust issues. It was clear that the traditional model of presidential patronage was no longer feasible, making Samsung adapt to the new political reality to keep its autonomy in its dealings with the government.

TSMC's early years coincided with major political changes in Taiwan Province of China. Despite these political turnovers, the relationship between the authorities and TSMC remained fairly stable. Private technology companies like TSMC had a high degree of autonomy despite receiving state support. TSMC's high degree of internationalization and cooperation with MNCs such as Philips, Intel, Apple, and AMD also made it less dependent on domestic political support and minimized political interference. This allowed TSMC to better resist political interference from the administration.

When supporting technology firms like TSMC, the government preferred a strategy of public-private joint ventures instead of pure government-owned firms. Political struggles and internal factional politics partially drove the government to play less direct and central role in technology companies (Hood, 1996). To avoid interest capture, the government purposely involved private investors to decrease the companies' dependence on the bureaucracy (Ouyang, 2006). When TSMC was founded in 1987, the government owned 49 percent of the company; Philips owned 2.5 percent while local investors had a 33.5 percent share (Hong, 1997).

As TSMC became highly successful by the 1990s and its reliance on government support decreased, the state allowed more private sector participation and autonomy while still providing some assistance. Even in 2002, the new government launched the "Two-Trillion and Twin-Star Industries" plan to promote the semiconductor and flat panel display industries, both of which exceeded two trillion NTD, or 64 billion US dollars in value (Yeh, 2008). As TSMC and other firms matured, the government allowed private companies and international investors to take over. This arrangement helped TSMC to develop and outgrow its dependence on government support (Ouyang, 2006) and eventually, it also minimized political influence.

Although Japan's political system has been marked by substantial turnover at the executive level, stability both at the party level and MITI provided continuity and autonomy for firms. Since Japan started developing semiconductor technology in 1976, it has had 22 Prime Ministers over 44 years, with an average of 2 years per Prime Minister. However, the Liberal Democratic Party (LDP) governed Japan for 38 of those 44 years. Due to the political turnover, firms like Hitachi tended to stay at a distance from the political process at the Diet (parliament), preferring a close relationship with MITI instead (Callon, 1995).

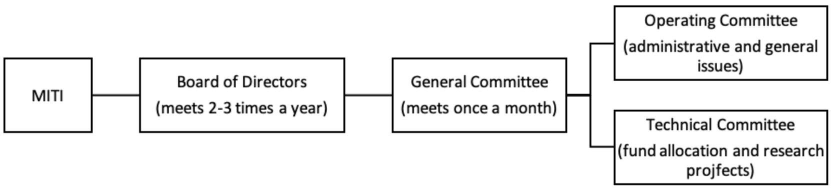
During the VLSI research consortium in the late 1970s, MITI gave Hitachi and other participating firms extraordinary autonomy, a characteristic of the general relationship under the Japanese system based on diversified conglomerates, or keiretsu. MITI worked with Hitachi and other firms mostly on a consensus basis. While MITI was nominally setting the agenda and leading the group, it allowed the firms to make decisions for the consortium itself. The VLSI research consortium was nominally run by the Board of Directors, made up of presidents of each of the five companies that met 2-3 times a year (Figure 1). However, most of the major decisions of the consortium were made by the General Committee, which comprised of the vice presidents or managing directors of each of the five participating companies. The General Committee met every month and made final decisions on behalf of the consortium. Overall, the participating firms had autonomy over much of their own research. Personnel management was completely up to the individual firms and they evaluated their own staff (Sakakibara, 1983).

Singapore has had extraordinary political stability since its founding, providing policy continuity and autonomy for the EDB. In its 60-year history, it had three Prime Ministers from the People's Action Party. Despite such a powerful executive and the ruling party, the EDB, like MITI in Japan, has been the key coordinating agency. EDB helped negotiate technology transfers with MNCs for CSM and allowed the company to stay at an arm's length from the internal political process. While CSM was a government-owned company, it was able to stay relatively autonomous from government meddling through the unique characteristics of EDB, an international staff and leadership, and close connections with other MNCs.

As EDB had a clear political mandate for investment promotion and industrial development, CSM avoided excessive interference from government agencies by dealing directly with EDB. EDB was endowed with the power to coordinate and command other state agencies to accomplish its goals. The clear mandate gave extraordinary powers to the EDB and fended off meddling from outside parties (Low, 1993).

CSM's foreign staff and external advisors and the firm's close links with MNCs also helped the company maintain autonomy from domestic political interference despite being an SOE. 60 percent of CSM's staff was international while 40 percent of staff was Singaporean nationals (Matthews, 1999). The

Figure 1: Organization of the VLSI research consortium in Japan



Source: Based on Sakakibara (1983).

international diversity helped ensure that CSM remained global and close to its international customers while insulating the company from local interests. For instance, out of the twelve members of CSM's Board of Directors in 2006, seven directors were foreigners, many from top foreign technology firms such as GE, Hitachi, and Motorola (Table 2). CSM also built close business partnerships with MNCs through equity shares. In 1994, in return for Toshiba's technology licensing, CSM sold 0.6 percent of its equity stakes to Toshiba. CSM also sold equity to US-based chipmakers Rockwell International, Actel, and Brooktree (Ramu, 1999). These equity shares helped tie CSM close to its international suppliers and encourage more coordination among the partners. International staff and close links with foreign firms knit CSM into a global system of technology companies while helping the company maintain its autonomy from political interference.

5. The state and the firm: Accountability

The ambitious policies, generous support, and autonomy given came with strict accountability based on concrete and measurable market signals for the firms involved. However, these firms did not evolve in general in environments where corruption and illicit relations between the corporate and political worlds did not exist. Yet the lack of much accountability in the corporate-political world did not preclude it for the support given to firms. Export quotas provided a yardstick in measuring performance while antitrust pursuits, or threats thereof, have kept firms focused on meeting their goals. Both domestic and international competition in a highly competitive industry was also a strong incentive to innovate and perform, or otherwise fold. Links with MNCs as a

Table 2: CSM's board of directors (2006)

Name	Previous Experience	Status
James Norling	Motorola Semiconductor	Foreign
Chia Song Hwee	Temasek Holdings	Domestic
Sum Soon Lim	Temasek Holdings/EDB	Domestic
Robert La Blanc	General Electric	Foreign
Andre Borrel	Motorola Semiconductor	Foreign
Charles E. Thompson	Motorola Semiconductor	Foreign
Tsugio Makimoto	Hitachi	Foreign
Tay Siew Choon	Singapore Technologies Holdings	Domestic
Peter Seah Lim Huat	Overseas Union Bank	Domestic
Philip Tan Yuen Fah	Overseas Union Bank	Domestic
Pasquale Pistorio	STMicroelectronics	Foreign
Steven Hamblin	Compaq	Foreign

Source: Data from SEC (2006).

source of demand helped improve efficiency and quality, especially for TSMC and CSM. Competition pushed even large firms like Samsung and Hitachi that had close relations with the state, to succeed as well.

In the 1960s-70s Korea, under Park Chung-Hee's rule, Samsung was held accountable by the government in terms of its export performance. Strict performance standards such as export quotas were imposed on chaebols in exchange for preferential treatment (Amsden, 1989). Firms were subjected to an increasing export quota set by the Ministry of Commerce based on their performance in the previous year. Firms that exceeded this quota were rewarded with subsidized credits, import licenses, and administrative support (Shapiro and Taylor, 1990). However, those that fell short were punished by tax audits, revocation of trading licenses, and even having their utilities cut off by the government (Adelman and Yeldan, 2000). In this respect, the state was ruthless in only allowing those with high performance survive, while letting others fail. Even many of President Park Chung-Hee's relatives and friends ended up in jail for fraud and misuse of state funds (Amsden, 1989).

The export metric was powerful, setting Samsung on a high-growth path, but as Samsung became successful and the direct state support gradually waned by the late 1980s, the firm got embroiled in many corruption scandals and antitrust investigations. Every chairman of Samsung appeared in court up to 2020 (Cain, 2020), and high-level convictions were followed by presidential pardons or reduced sentences.[2] By the 1990s, public opinion against the chaebols had turned highly unfavorable, and the state pursued both antitrust investigations and bribery charges.[3] The pattern of corruption charges and court trials and political interference in sentences indicate the difficulty in upholding accountability toward chaebols although the trials and antitrust investigations showed at least some attempt in making chaebol leaders accountable for political corruption. Yet despite all these tribulations, Samsung and other chaebols have achieved impressive success.

Although the chaebol system supported Korea's economic development, it also had flaws that distorted its decision-making. First, due to their preferred access to financing, chaebols tended to overinvest, make risky investments, or continue investing in declining industries despite lower efficiency gains. Even after the government stopped providing direct credit to the chaebols, their sheer size allowed them easier access to credit. Second, chaebol heads, the so-called chongsus, often pursued investments such as creating new firms and overextending the portfolio of the company to increase the chongsu's overall image and enhance his political influence. Third, the chaebols were family-based organizations and its senior positions were still often filled by relatives of the chairman even after Samsung moved toward a more meritocratic system in the late 1990s. Lastly, chaebols often practiced internal trading and cross share-holding among chaebol affiliates. This arrangement gave more power to the chairman to control the company through "tunneling" among different units, setting up a complex network of cross shareholding. Samsung also purchased products from sister companies even as external non-affiliated firms offered better rates (Murillo and Sung 2013).

Samsung was able to overcome these limitations through internal restructuring during Korea's democratization waves. Samsung's internal reforms coincided with increasingly negative public perception of chaebols in the 1990s. It adapted a more meritocratic and more decentralized system to keep up with the political realities. These changes helped control the power of the chongsus and some of the disadvantages of the chaebol system by instituting more checks and balances on the company. While the public had limited direct ways to hold chaebols like Samsung accountable, Samsung responded to political pressures to change its business model to adapt to a more democratic

[2] In 1996, Lee Kun-Hee, the founder of Samsung, was sentenced for bribery to two former Presidents, but was pardoned by the sitting president, Kim Young-Sam in 1997. Lee received another presidential pardon in 2009 by President Lee Myung-Bak after being found guilty of tax evasion (Choe, 2009). In 2017, Lee's son, Lee Jae-Yong, was again sentenced for bribery and corruption. This time he did not receive a presidential pardon, reflecting public opinion criticizing the government for repeated pardons to chaebol leaders. However, the junior Lee's sentence was significantly reduced (Neuman, 2018).

[3] Kim Young-Sam's government (1993–1998) began to pursue a campaign against the chaebols. In 1996, Kim upgraded the Fair Trade Commission to the ministerial level, allowing it more authority to pursue antitrust investigations (Ju, 1997). Several chaebol chairmen, including Lee Kun-Hee of Samsung and Kim Woo-Jung of Daewoo, were prosecuted on bribery charges (Murillo and Sung, 2013).

and innovation-driven economy. These reforms helped Samsung maintain its competitive edge.

Unlike Korea, Taiwan Province of China did not give explicit export quotas to its technology companies, but its technology firms had to enter into collaboration with foreign companies to supply them with components, expand its international network, and focus on exports to scale up and make profit. Out of 315 semiconductor production companies in 2001, very few had vertically integrated operations (Lin, 2003). Instead, they specialized in a very specific stage of the production process and competed with other suppliers on the international stage. These companies often received their specialized technology, thanks to support from the ITRI or other government sponsored research institutions.

Competition in a highly competitive industry domestically and internationally acted as a yardstick for the government providing various benefits to technology firms. TSMC was situated in Hsinchu Technology Park, an innovation park area aimed to attract entrepreneurs and talents in the technology industry. Thanks to its location in the park, TSMC was able to receive tax holidays, duty-free imports of key equipment, raw materials, and semi-finished goods, exemptions from commodity taxes on exports, low-interest loans, and R&D matching funds (Meaney, 1994). More important, the government provided its research results and benefits to multiple companies to commercialize instead of handing it to only a few large corporations. Domestic competition made firms innovate and reduce cost in a highly saturated market. Chen and Jan (2005) document that TSMC was engaged in fierce competition with UMC, another local semiconductor company spun off by ITRI. This competition forced both to invest relentlessly in research, helping make them the top two foundry companies in the world.

Overall, while the government provided support in terms of technology transfer and financing, the government did not favor one company over the other. Instead, the government successfully created an industry, helping companies excel on the world stage. The companies were held accountable by market forces and competition with peers domestically and internationally. In this sense, as Lin (2003) observes, and paraphrasing Wade (1990), the government "made" rather than "picked" the winners in the technology sector.

In Japan, although MITI had generally given Hitachi and other semiconductor firms a high degree of autonomy, the collaboration was not always smooth. In the case of the VLSI research consortium, MITI initially wanted 100 percent of the research to be conducted jointly in MITI labs. However, Hitachi and the other firms were reluctant to collaborate. Instead, they tended to protect their own interests and viewed their competitors with suspicion (Callon, 1995). As one of the managing directors at the consortium observed that the firms "made no attempt to disguise their hostility; they discussed and discussed without disguising their selfish desires" (Sakakibara, 1983). This tension showed that despite the eventual success of the consortium, there were different priorities among MITI and the firms.

The close relationship between firms and senior members of MITI and the Japanese government was both beneficial and prone to corruption. Since the 1990s, Japanese public opinion has turned negative toward Hitachi and other keiretsu companies for their dealings with senior government officials (Albrecht et al., 2009). In a practice termed golden parachute (*amakudari*), senior government officials, usually between 55-60 years old, would often be offered high paying corporate jobs after their retirement as they made way for younger officials. This arrangement became institutionalized in post-war Japan to compensate the officials for their service as public salary was considerably lower than that of the private sector (Carpenter, 2012). However, this system built a web of personal connections between government officials and keiretsus and gave incentives for government officials to give preferential treatments to certain firms (Colignon and Usui, 2003) such as bid-rigging practices (Carpenter, 2015). This system also ensured the close collaboration and coordination between MITI and private firms, especially when the alumni of the Ministry were at the helm (Johnson, 1982).

Despite these challenges in their relationship with MITI and government officials, Hitachi and other semiconductor firms used the support provided to compete, innovate and perform. Like the semiconductor firms in Taiwan Province of China, both domestic competition and the global market gave firms no choice but to succeed or falter. It was probably a fragile equilibrium as too close relations between the firm and the state would probably have resulted in more corruption and less success.

Compared to Samsung, TSMC, and Hitachi, Singapore's CSM received a relatively low degree of support from its government. EDB's main source of financial support for CSM was through research grants and technology transfers with MNCs. As a government-owned company under Singapore Technology Group, CSM also benefited from the managerial expertise of the state agency. However, the EDB had a hands-off approach and did not inject high subsidies to CSM, fearing such state support would distort markets. After the initial support, CSM was expected to compete with private firms without preferential treatment. The research grant provided by the government was also relatively low compared to the cases in Korea or Taiwan Province of China. In 2004, CSM spent 120 million US dollars on R&D activities, but only 12.1 million dollars came from government subsidies (SEC, 2006).

CSM was kept accountable directly by competing on the market. Government support came with the understanding that CSM would have to compete with private companies and MNCs with no preferential treatment. This arrangement in general was typical of Singapore's approach to the commercial ownership of companies by Temasek Holdings, which operates independently of the government. As the semiconductor industry became more capital intensive, the EDB was unwilling to inject significant cash to help CSM keep up with the technology upgrades and research investments. Instead, in 2009, the government decided to sell off its company after it became unprofitable (Online Citizen, 2018).

6. Changing with the times: Adaptability

One of the key elements of success is to adapt to changing circumstances. In the cases under study, we observe that firms adapted to changes in the orientation and incentives of industrial policy. Adaptation also took place *organically* to tackle emerging trends in international markets along technology, demand, or the structure of value chains in some cases beyond or in opposition to the orientation of the industrial policy of the day. Organizational restructuring such as decentralization and coordination among units, operational autonomy with the financial constraint, and a more meritocratic system helped firms innovate and find new markets. Integration into domestic and international research networks, collaboration with MNCs, customer feedback, and a heavy investment in in-house research capabilities also helped firms adapt quickly to technological and customer preference changes and keep the competitive edge. However, the success was not guaranteed as the example of CSM illustrated. Despite investing in R&D and innovating, the company did not achieve a large enough scale, eventually losing out on innovation and competition.

In the early days, export quotas and state support helped Samsung Electronics grow fast, but it also encouraged short-term gains rather than long-term planning. Chaebols often had to meet increasingly higher export quotas to compete for government support and tended to focus on creating short-term wins and producing high quantities (Kim 1997). While this approach worked initially, it also produced unintended consequences. The incentive structure created by government planners did not encourage innovation investment. Samsung became successful in copying and producing products of competitors and wage price wars, often with government subsidy support, to win sales. But during that time, it had very limited in-house original research and development capabilities, lacking the capability to innovate and potentially hurting its long-term growth. Furthermore, since Samsung's sales were dependent on foreign manufacturers, it did not see the need for foreign marketing, and instead focused solely on the production side. Until 1978, Samsung Electronics was blocked by the main corporate office from conducting international marketing operations. From Samsung's point of view, entering new markets was a waste of resources; instead, by locking on its relationship with the foreign manufacturers, it could achieve its export quotas and receive the government support needed.

Locked in the low-end market, dependent on foreign manufacturers and with very limited in-house research capabilities, Samsung entered the 1990s with some significant potential weaknesses. As domestic and international circumstances started changing in the 1990s, Samsung needed to adapt to changing markets to translate the firm's initial success into long-term sustained growth.

The first challenge of the 1990s came from the international environment that has become increasingly less favorable to Samsung. In 1988, the US and the European Community withdrew the generalized system of preference (GSP) privileges from Korean electronic goods. As Korean products, such as Samsung's

DRAM, became successful on the international stage, Korean firms now had to compete on a more leveled playing field as its main competitors. By the 1990s, Korean won had also appreciated by about 20 percent against the dollar, making an export strategy based primarily on cost increasingly challenging for Samsung's electronics. Lastly, by the 1990s, Samsung Electronics' sales began to stagnate in the saturated market, and its former strategy of relying on foreign manufacturer demand instead of creating its own market had reached a point of diminishing marginal returns (Lee and Lee, 2007).

Another challenge Samsung began to face was domestic liberalization, which made Samsung vulnerable to international competitors in its home market. Throughout the 1970s and the early 1980s, the Korean government protected domestic manufacturers by setting high tariff rates and other non-tariff barriers. However, by the late 1980s, the government began to change its incentive structure. The EPB, in particular, began to advocate for consumer interests and pushed for trade liberalization (Amsden, 1992). As a result, Samsung and other chaebols faced increased foreign competition in their domestic markets. In 1989, import quotas on consumer electronics were removed, and in 1991, foreign retail outlets were allowed 10 stores in Korea (Kim, 1997).

In addition to dealing with market challenges, Samsung had to confront considerable political turnover. In 1987, South Korea held its first "free and direct" election (Han, 1988), and in 1993, the country saw its first elected civilian president (Chu, 1998). In addition, political pressure on Samsung and other chaebols to reform came to a watershed moment during the 1997 Asian Financial Crisis. Faced with liquidity problems, the chaebols turned to the government for help. A more rigorous regulatory framework was set up and the Korean Stock Exchange was opened up to foreign investors. The stock market started replacing bank loans as the major funding source for Samsung and other chaebols, promoting greater transparency (Murillo and Sung, 2013). Therefore, as the state changed its ambition and goals, Samsung needed to adapt accordingly to stay competitive.

Faced with these challenges, Samsung adapted with organizational restructuring efforts to increase its competitiveness and pursue an innovation-based growth strategy. By facilitating horizontal integration, allowing more autonomy for affiliates, changing its emphasis from quantity to quality, pursuing a more meritocratic system, Samsung adapted by increasing its competitiveness and becoming more flexible. The previous structure encouraging conformity with central authority, short-term gains, and overly ambitious projects gave way to operational autonomy with the financial constraint.

Samsung increased its horizontal integration to enhance coordination across different groups, especially between production, marketing, and research departments. One of the key weaknesses in Samsung's corporate strategy in the 1980s was the limited involvement of the production department in early stages of new projects (Koh, 1992). Instead, projects were simply selected by corporate headquarters for expected short-term gains without considering long-term impact. Communication was also lacking between production and marketing units and Samsung's R&D center. The new corporate set up attempted to streamline consumer feedback mechanism to ensure the research and production units respond effectively to market demands.

The consolidation of the management system helped ensure more coordination across horizontal units and faster adaptability to changing market trends. In 1991, Samsung Electronics set up a strategic management unit to consolidate its technology management system and to improve the dissemination of knowledge throughout the group. The firm continued to merge and consolidate its management system, merging the video and audio business divisions in 1993 and integrating all electronic products under a single CEO. Kim Kwang Ho, the previous head of Samsung Electronics' highly successful semiconductor unit, was put in charge of all electronics affiliates in 1994, helping fully integrate the previously fractured affiliate system into one whole unit (Kim, 1998).

As Samsung affiliates were consolidating its management system, the central corporate office was decentralizing its power structure, allowing affiliates more flexibility to pursue innovation. For most of the 1980s, Samsung's centralized corporate structure had limited the transfer of technological capabilities from the center to overseas affiliates. As Samsung expanded its international operations, this self-imposed limitation became a barrier for the company. As the company needed to interact with a larger number of economic actors, both outside and inside the firm, each organization within Samsung's corporate empire needed greater autonomy. A centralized corporate bureaucracy hindered the ability for affiliates to effectively carry out its operations. As a result, in 1995, Samsung started to decentralize its decision-making authority to its overseas units and affiliate groups while giving them clear mandates to prevent unnecessary competition among units. Samsung established five regional headquarters around the world, each with enhanced responsibilities and authority to make decisions. Affiliates also increased their operational autonomy from the central corporate office.

Samsung also underwent a fundamental shift in its strategic planning system. For much of the 1970s and 1980s, at the corporate headquarters, the planning team (Strategic Planning Office) took the decisions, with a supplementary input from the finance team. However, starting from the late 1990s, the finance team gradually took over the strategic planning process, eventually becoming the most influential player after the Chairman. Unlike the ambitious growth-driven planning team, the finance team preferred more cost-benefit analysis and was more concerned with internal efficiency than external growth. By the late 1990s, Samsung scaled down ambitious diversification projects, focusing on increasing its internal efficiency, preferring quality over quantity.[4] The group made a push away from a price-driven growth in the low-end market, instead

[4] In 1999, the finance team started applying the EVA (Economic Value Added) method in assessing affiliates' performances with evaluation based on quantitative goals.

opting to develop the capability to compete in the medium- and high-end markets (Kim, 1998). The Strategic Planning Office shifted to formulating a long-term strategy for the group, identifying new business opportunities and conducting internal audit (Park, 2008). In a sense, the Strategic Planning Office became the new EPB for the firm, setting rules and giving units autonomy within that framework, while holding units accountable for their performance.[5]

The adoption of a more meritocratic system with promotion based on performance rather than seniority and loyalty to the company, was an important response to both competitive and political pressures. The firm needed to attract talent and have a more dynamic staff base for its development. The democratic transition in the country also called for a shift in norms at the firm-level. Like the political system, Samsung's corporate structure needed to allow for more staff input and greater flexibility in personnel.

Traditionally, Samsung relied on political connections and had little incentive to promote a dynamic corporate structure, opting for a highly hierarchical system based on conformity and loyalty. For instance, in the early 1990s, the average age of general managers was 43-55 years old while that of staff was 26 years old with other managers' age falling in between (Pucik and Lim, 2001). Another major problem with the seniority system was that by the early 1990s, Samsung had more senior-level personnel than senior-level positions, keeping personnel it did not need and paying high salaries. Since staff were automatically promoted based on the number of years they stayed in the firm, there was an overflow of staff who did not have corresponding posts to match their seniority. Samsung started to run into the problem of a dual system as senior-level staff were often given the title of General Managers or Deputy General Managers but were not placed in positions of power. By 1993, only about 42 percent of those with a title of General Manager actually assumed the corresponding post in a unit (vs. 61 percent in 1989), a proportion that was only a staggering 8.5 percent for Deputy General Managers (vs. 39 percent in 1989) (Pucik and Lim, 2001).

In adopting a more meritocratic system, Samsung stopped the practice of placing hard limits on staff promotions and allowed more mobility for blue collar workers in its promotion system. The firm put out a guidance on average years required for promotions. If staff members excelled at their performance, they could be promoted without seniority. The automatic promotion was not expected any more. In addition, human resource policy shifted to allow more equality in promotions. Traditionally, Samsung recruited heavily from the elite institutions in the country, favoring graduates from Seoul National University, Yonsei University, and Korea University. The new policy relied on the written exam scores for promotion decisions. While the new promotion strategy was

[5] In 2006, Samsung further restructured its corporate structure by slashing staff numbers at its headquarters' Strategic Planning Office from 147 to 99. This change further decreased what affiliates saw as "excessive control" by headquarters over its operations, allowing affiliates more flexibility while still answering to financial constraints set by the headquarters.

still not fully based on job performance, it did create opportunities for staff without degrees from elite universities for promotion (Pucik and Lim, 2001).

Unlike Samsung with its sprawling economic empire, TSMC specialized in one area instead of diversifying into multiple sectors and adapted to market changes, quickly climbing the technological ladder, through participation in international networks, collaboration with MNCs on technological research, and a commitment to in-house innovation research. TSMC's operation was focused on producing semiconductors (Liu et al, 2005). While TSMC initially enjoyed government support through ITRI, it had to adapt to changing domestic and international trends, although in a different way than Samsung. TSMC's model indicates a different approach than that of Samsung, especially how a specialized firm can compete with large conglomerates and remain the top semiconductor company.

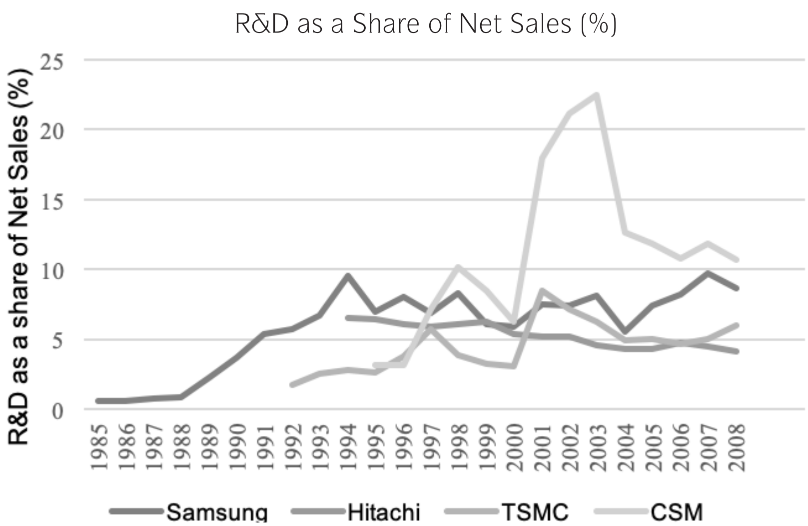
TSMC rapidly upgraded its production technology through establishing collaborative networks with international information technology (IT) industries.[6] It embedded itself in the international IT network, actively participating in many joint research initiatives. In 1996, TSMC joined the International 300mm initiative as a member of SEMATECH, a consortium of semiconductor manufacturers in the US. Through SEMATECH, TSMC was able to participate in developing a new generation of semiconductor technology, which helped it stay at the technological frontier. TSMC also gained access to international business networks through the consortium, building relationships with other semiconductor firms and cooperating on projects. For instance, TSMC worked with CPU manufacturers like AMD and Cyrix to develop the PC-133 SDRAM, which overtook Intel's Rambus architecture to become the mainstream CPU architecture, giving TSMC a major edge in semiconductor manufacturing (Ouyang, 2006).

Besides joining research networks, TSMC also worked closely with MNCs to jointly develop technology and rapidly upgrade its technological capabilities. Initially, TSMC was dependent on Philips, a major stockholder, for technology transfers. Under the equity agreement during TSMC's founding in 1987, Philips transferred its 2-micro and 1.5-micron VLSI wafer-fabrication technology at no charge to TSMC in exchange for access to foundry service. This agreement also allowed TSMC to use patents from MNCs such as IBM, Intel, and Toshiba under Philip's cross-licensing arrangements, giving TSMC access to the latest technology (Lee et al, 2010). This helped TSMC expand its own in-house research center and build upon these existing patents, gradually entering the production of SRAM, SDRAM, and DRAM chips (Figures 3 and 4). Between 1997 and 2003, TSMC rapidly expanded its technological capabilities, building

[6] The founder of TSMC Morris Chang's extensive personal network and managerial experience in the US helped give TSMC a huge advantage in tapping into international research networks. A graduate of MIT, Chang worked at Texas Instruments for 25 years (1958 – 1983), eventually serving as the group's Senior Vice President responsible for its global semiconductor operations (Hsieh et al, 2002). In 1985, Chang was recruited to become the president of ITRI and lead the work on semiconductor projects (Ouyang, 2006).

nine fabrication plants and developing the technology to produce the latest technology wafers (Lee et al., 2010). Thanks to heavy investment in in-house research, within the first decade of its founding, TSMC had already outgrown its dependence on Philips for technology transfers. By the early 1990s, TSMC had already started achieving better yield performance than Philips. It made its transition to 0.8-micron process technology without significant help from Philips (Matthew and Cho, 2000).[7]

Figure 2: R&D intensity (1985-2008)



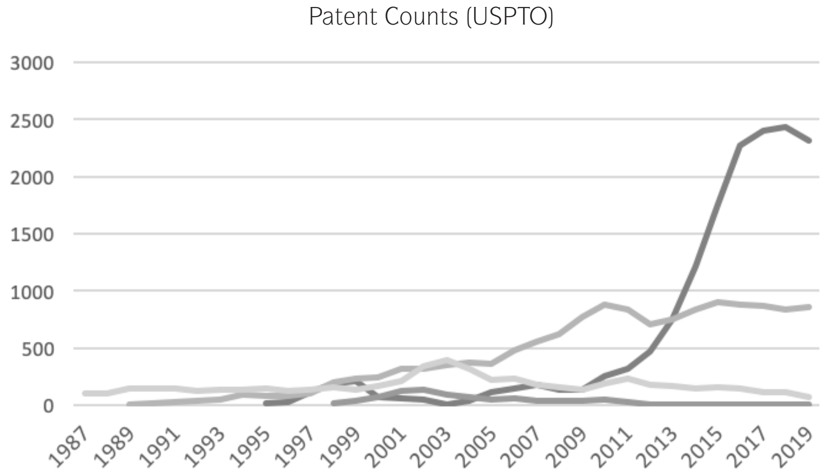
Source: Annual financial reports and SEC filings of companies.

TSMC adapted to changing state support by diversifying its funding sources and seeking capital on the international market. State financial contribution was important in the early stages of TSMC's development. The government mobilized reluctant local private investors and committed state funding to help finance TSMC's research and production activities (Ouyang, 2006). However, by the 1990s, the state started stepping back from its earlier commitments, allowing the private sector to take over (Meaney, 1994). Consequently, TSMC

[7] TSMC also acquired the latest process technology through providing foundry services to leading multinationals such as NEC, AMD, and Fujitsu in exchange for technology transfer or license (Chen and Jan, 2005). For example, in 1994, AMD doubled its production capacity for its Am486 microprocessor thanks to TSMC's foundry. In return, AMD transferred its 0.5-micron processor technology to TSMC (Lee et al, 2010).

listed its stock on New York Stock Exchange in 1997, the first company from Taiwan Province of China to do so (Chen and Jan, 2005).

Figure 3: Patents filed at uspto in semiconductors (1987-2019)



Source: Annual financial reports and SEC filings of companies.

Similarly, in Japan, Hitachi pursed a strategy of internationalization, participated in research consortiums, and engaged with customers. The firm tapped into global production networks in East Asia to help lower its price and ensure the best quality. In Korea, Hitachi had a close partnership with LG that helped expand Hitachi's production capabilities (Choung et al., 2000). Hitachi also worked closely with the United Microelectronics Corporation (UMC), a major semiconductor manufacturer in Taiwan Province of China and the first ITRI spin-off in the 1970s. In 2000, the two firms launched a joint venture to produce 300mm wafers, in which Hitachi held a 60 percent majority stake (CNET, 2002). These partnerships that Hitachi developed helped enhance its production capabilities and tap into the labor and talent pools of its East Asian neighbors.

Hitachi continued to participate in research consortiums to stay on the technological forefront. In 1996, Hitachi was one of ten Japanese firms to participate in the Semiconductor Leading Edge Technologies (Selete) research consortium. With other members (NEC, Toshiba, Mitsubishi, Fujitsu, Matsushita, Sanyo, Oki, Sharp, and Sony), Hitachi invested in the development and tool evaluation of the 300mm wafer and advanced technology development such as lithograph and computer-aided designs. It also committed approximately 280 million US dollars towards semiconductor research at its laboratory in Yokohama City (Ham et al., 1998). Through both in-house research and joint efforts through research consortiums, Hitachi continued to innovate and remain competitive at the global forefront.

Moreover, Hitachi kept a close relationship with customers through Japan's unique keiretsu system that allowed the firm to adapt its technology through direct socialization and exchange with customers. Under the keiretsu system, Hitachi would enter into stable strategic partnership with certain firms. The two firms would also exchange personnel through short-term personnel exchange, long-term personnel transfers (shukko), and stable interorganizational teams that exchanged ideas. For instance, Hitachi had a long-term partnership with Japan Railways, supplying it with both the hardware and software for control systems. Hitachi would then assign senior personnel to serve in-house at Japan Railways. This arrangement helped relay information back to Hitachi, facilitating a quick response and adapting to the changing needs of its customer (Lincoln et al., 1998). The close business relationships of the keiretsu system created a learning process and knowledge creation symbiosis between Hitachi and its partner firms. Even as administrations changed in Japan, Hitachi was able to continue to adapt to changing government goals to stay competitive.

Like TSMC, Singapore's CSM, established in 1987, the same year as TSMC, vigorously pursued ventures with MNCs. Initially created in a technology transfer agreement to supply two US based companies, Sierra Semiconductor and National Semiconductor, it faced troubles when National Semiconductor dropped out of the supply agreement. As a capital-intensive industry, without a large customer base as well as the resulting economies of scale, it would have been difficult to compete on the international stage. CSM adapted by becoming a pure foundry model like TSMC (Wong, 1999). The company did not carry its own brands but rather supplied a range of other companies to maximize its customer base and reduce costs of production. CSM entered into new supplier partnerships with American and Japanese technology firms that helped it reach the scale of production necessary for its operations (Matthews, 1999).

CSM also entered into research agreements and joint ventures with MNCs to acquire advanced technology. In 1997, CSM and Toshiba agreed on a 5-year partnership where Toshiba agreed to license its embedded DRAM technology to CSM starting with 0.35-micron and migrating to 0.25-micron. The partnership allowed Toshiba to have a secure supplier. In 1998, CSM created a joint venture with Lucent, Silicon Manufacturing Partners (SMP), employing more than 800 people in Singapore to create integrated circuits (CNET, 1998). In 1999, CSM entered into another joint venture with HP to create Chartered Silicon Partners (CSP), which produced up to 30,000 eight-inch wafers per month (SFGATE, 2012). These collaborations helped CSM to rapidly acquire advanced technology from foreign partners. Over 1990-2002, CSM was able to leapfrog from 1.5-micron DRAM technology to 0.25-micron in just over a decade, acquired from Sierra Semiconductor and Toshiba.

CSM recruited heavily foreign talent to help with its operations. In 1999, 40 percent of CSM's staff were Singaporeans, mainly managers, engineers, and technicians while the other 60 percent were foreign (Matthews, 1999). The foreign employees brought the technological know-how and international connections, allowing CSM to continue to expand its global presence.

CSM enjoyed rapid expansion throughout the 1990s. Within the first decade of its establishment, CSM owned five fabrication facilities, opening up its sixth fabrication facility in 2000 and the seventh in 2005 (SEC, 2006). By the 2000s, CSM had emerged as one of the largest and most successful semiconductor foundries in the world (Table 3).

Table 3: CSM Production Facilities

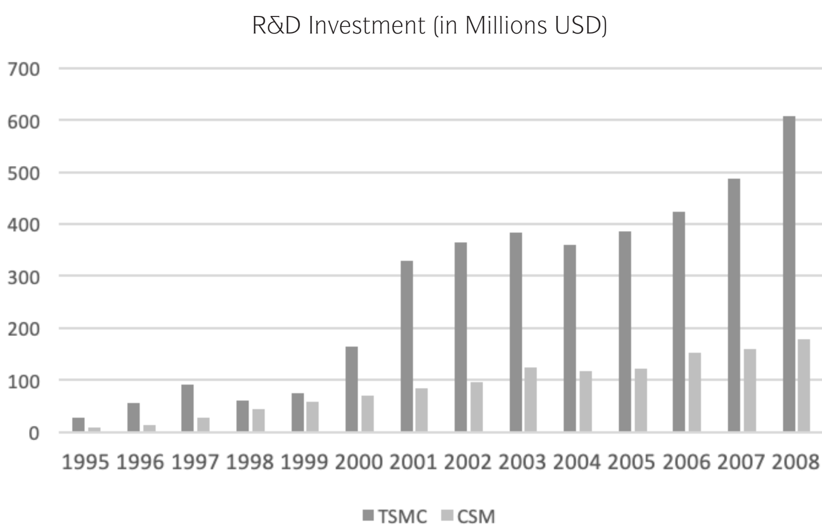
Facility	Production Started	Wafer Size	Full Capacity (wafers/month)	Process Technology
Fab 1	1989	6-inch	-	-
Fab 2	1995	8-inch	45,000	0.6 to 0.3µm
Fab 3	1997	8-inch	23,000	0.35 to 0.18µm
Fab 3E (Tampines)	1998	8-inch	34,000	0.22 to 0.153µm
Fab 5 (SMP)	1999	8-inch	23,000	0.25 to 0.13µm
Fab 6 (CSP)	2000	8-inch	37,000	0.25 to 0.11µm
Fab 7	2005	12-inch	30,000	0.13µm and smaller process geometry technologies

Source: Figures from SEC (2006).

However, by the mid-2000s, CSM started showing trouble in keeping up with its main competitors like TSMC. Unlike TSMC, which invested heavily in in-house R&D, CSM's growth model had been too reliant on foreign partnerships and foreign technology transfers. In the 1990s, this was a successful model since R&D was not a bottleneck and technology could be licensed at a reasonable price. But as semiconductor technologies became more sophisticated and fabs more costly (in billions of US dollars), CSM slowly lost its competitive edge.

The lack of scale and sufficient in-house research expertise created big headwinds for CSM. By the mid-2000s, as fabrication methods started surpassing the 90 nm node, R&D became exponentially more expensive. Although CSM did invest a comparable share of its net sales in R&D (Figure 2), it was much smaller in absolute numbers (Figure 4) that translated to lower patent count (Figure 3). CSM had to pay higher fees for imported technology licenses from companies such as IBM, which began to charge more after the mid-2000s. In addition, with each succeeding technological node, production became more capital intensive. In the late 90s-early 2000s, fixed investment (property, plant, and equipment) of CSM was more than 6 times lower than that of TSMC. After the 65 nm node mark, CSM began to run into serious capital issues (Online Citizen, 2018). CSM invested most of its capital in production facilities and foreign technology transfer licenses, and it did not develop a sufficient in-house research capability compared to TSMC. On the high-end, TSMC was able to save on licensing costs and offered cheaper advanced products. On the low-end, Chinese producers began to offer relatively cheap products and could license similar technologies from IBM (Online Citizen, 2018). From 1995 to 2005, CSM accumulated substantial losses (Figure 5).[8]

Figure 4: R&D investment (1995-2008)



Source: Annual financial reports and SEC filings of companies.

7. Conclusion

The success of the semiconductor industry in East Asia is largely due to the symbiosis between the state and the firm. The 4A framework presented—ambition, autonomy, accountability, and adaptability—highlights the key features of the state-firm collaboration and lessons for success. The cases of Samsung of Korea, TSMC of Taiwan Province of China, Hitachi of Japan,

[8] In 2009, CSM was acquired by an Abu Dhabi-based company, Advanced Technology Investment Company (ATIC) (Sperling, 2009).

and CSM of Singapore illustrate how these firms responded to incentives, pursued their operations, remained accountable, and adapted to the changing circumstances. It also shows that a number of East Asian economies simultaneously led an effort to develop the same frontier technology and at a relatively early stage of development for Korea and Taiwan Province of China. For instance, Korea had a GDP per capita in the 1970s similar to that of Tunisia in 2017. Korea recognized the technologies of the future, and being far from the frontier did not deter them from leapfrogging.

Figure 5: Net profits (1995-2008)

Source: Annual financial reports and SEC filings of companies.

Ambitious goals set by the state were followed by an equally ambitious industrial policy to jumpstart the industry and facilitate firm entry into this sophisticated sector. The spark became a sustained success as firms produced, exported, and innovated. At the same time, the arm's length approach of the state gave firms the needed operational autonomy. The specific institutions in charge of industry development such as MITI in Japan, EDB in Singapore, EPB in Korea, and ITRI in Taiwan Province of China enjoyed substantial autonomy and were the firms' main counterparts minimizing political interference. Close ties with domestic private investors and foreign MNCs and ownership stakes maintained the healthy relationship between the state and the firm.

For the incentives and support provided, strict accountability based on concrete market signals was enforced, which was achieved in an environment where corruption and political meddling were prevalent. Export quotas provided a yardstick in measuring performance, especially in the early stages. Domestic and international competition in a highly competitive global industry was a strong incentive to find new markets and customers and more important, innovate. Links with MNCs further improved efficiency and quality, especially for TSMC and CSM. Competition also pushed even large firms like Samsung and Hitachi, despite their cozy relations with the state, to succeed. Meanwhile, these economies were not (and still are not) immune to corruption and nepotism. In other words, the low quality of institutions did not prevent the enforcement of accountability where it mattered most.

Adapting to the changing environment was instrumental for firms and the industry to survive. Organizational restructuring such as decentralization and coordination among units, operational autonomy of affiliates facing the financial constraint, and a more meritocratic system helped Samsung deal with the political and global changes, pushing it to innovate and find new markets. TSMC, Hitachi, and CSM participated in domestic or international research networks and collaborated with MNCs to acquire technologies and climb the technological ladder. All of the firms attracted talent, whether domestic or foreign, and invested heavily in in-house research capabilities, allowing them to keep their competitive edge. However, the case of CSM illustrates that despite investing in R&D and innovating, it was not sufficient as the company did not grow large enough and could not spend more in absolute terms, eventually losing out on innovation and competition. Overall, CSM was a success as it enjoyed years of high profits and created high paying jobs and spillovers to the rest of the economy. However, and ironically as an SOE, it was eventually sold precisely because it was under pressure to avoid taking too much risk in investment and in-house R&D.

The 4A model has policy implications for both advanced and developing economies to help design planning institutions and support domestic industrial upgrading. As sustained growth is about sophisticated sectors, the state-firm collaboration as exemplified by the 4A features—ambition, autonomy, accountability, and adaptability—is key to success. The lessons suggest that the state should be ambitious with not only its goals but also its policies, pushing firms to export and innovate while giving them autonomy to achieve those goals. The support and autonomy must come with strict accountability, which is best met by domestic and international competition. Both the state and firms need to adapt quickly to changing circumstances as this is probably the most important and difficult part toward long-lasting success or eventual failure.

Economies still have major opportunities to pursue industrial upgrading. On the one hand, the COVID-19 pandemic and the rise of economic nationalism may have slowed the pace of globalization. Advanced economies are localizing their high value-added industries, such as the US and EU's push for local semiconductor production capacity. This trend may make the export-orientation growth model of East Asian economies relatively more difficult than previously. On the other hand, new technologies such as AI, green technology, and financial technology have created new areas for governments to push for high-tech industrial upgrading. The shake-up in global supply chain due to the COVID-19 pandemic also offer opportunities for countries to build up their sectors for a resilient global supply chain. Overall, the story of the East Asian economies show that markets can be created, requiring governments to design the right kind of incentives to help its domestic firms succeed.

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Appendix. Background and additional details: Samsung, TSMC, Hitachi, and CSM

Table A1. Summary of firm characteristics

Company	Base	Company Founded	Start of Semiconductor Activity
Samsung Electronics	Korea	1938	1984
TSMC	Taiwan Province of China	1987	1987
Hitachi	Japan	1910	1976
CSM	Singapore	1987	1987

Source: Firm websites.

Samsung Electronics (Korea)

Founded by Lee Byung-chul in 1938 under Japanese colonial rule as a trading company, Samsung has become an economic giant and a major driver of South Korea's economic development. From humble beginnings, Samsung specialized in fertilizers and sweeteners until it entered the electronics industry in 1969 through a joint venture with the Japanese electronics company Sanyo, which provided Samsung with significant technology know-how and opened up export markets (Chang, 2006). The joint venture started producing black-and-white televisions and expanded its production to other home appliances such as refrigerators, air conditioners, and washing machines (Moon and Lee, 2004). Supported by Korea's Five-Year Plans, the company continued to move up the value chain, entering the semiconductor industry in 1984, and started producing mobile phones in 1988. Overtime, Samsung transformed from a parts supplier for American and Japanese electronics firms to competing with American and Japanese multinationals (Chang, 2006).

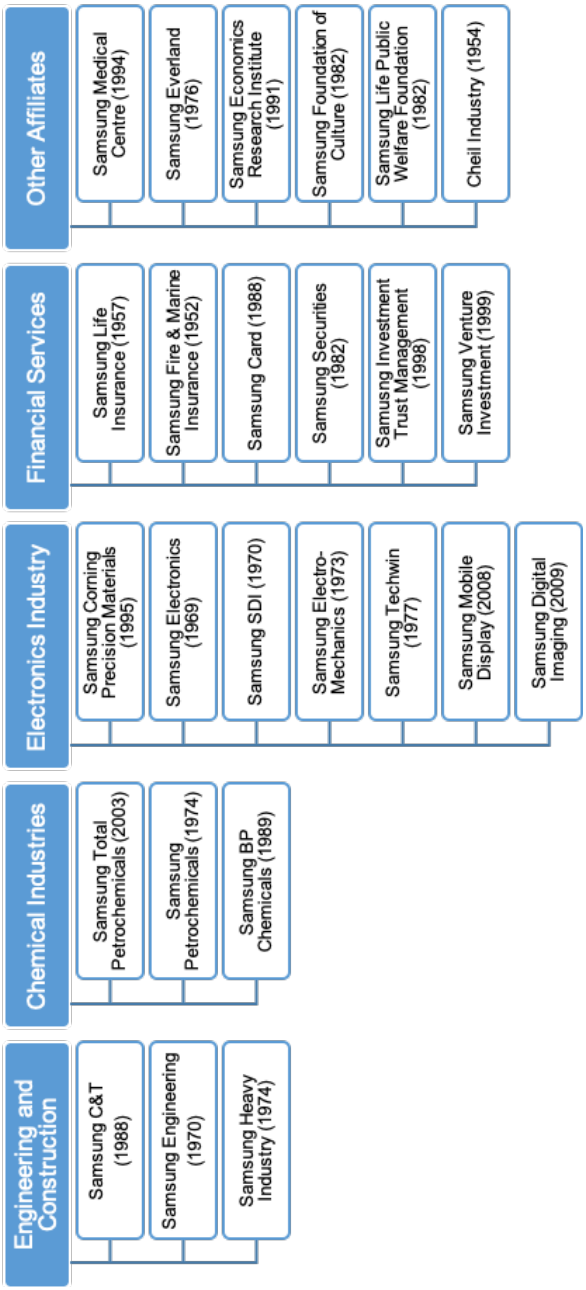
Table A2. Overview of Korea's Five-Year Plans

Plan	Years	Main Goals	Leaders
First Five-Year Plan	1962 – 1966	Creating a self-sustained and export-led economy through technology investment, education, and shift from agriculture to manufacturing	Park Chung Hee
Second Five-Year Plan	1967 – 1971	Creating a modern economic structure through building major highways and supporting steel and petrochemical industries	Park Chung Hee
Third Five-Year Plan	1972 – 1976	Heavy Industry Drive especially in five "strategic" fields: (1) electronics, (2) shipbuilding, (3) machinery, (4) petrochemicals and (5) non-ferrous metals	Park Chung Hee
Fourth Five-Year Plan	1977 – 1981	Continuation of Heavy Industry Drive	Park Chung Hee Choi Kyu Hah Chun Doo Hwan
Fifth Five-Year Plan	1982 – 1986	Shift from heavy industries to technology driven products	Chun Doo Hwan
Sixth Five-Year Plan	1987 – 1991	Aiding structural transformation through acceleration of import liberalization and phasing out direct subsidies to industries.	Chun Doo Hwan
Seventh Five-Year Plan	1991 – 1996	Development of high-tech industries in seven provincial cities to aid geographic distribution of industries throughout Korea	Chun Doo Hwan Kim Young Sam

Note: The Seventh Five-Year Plan was scrapped in 1993 after the election of Kim Young Sam with a new economic plan that matched his term length. After the election of Kim Dae-Jung, the practice of setting Five-Year Plans was discontinued altogether.

Samsung has affiliates across almost every aspect of the Korean economy, from construction to life insurance, hotels, and resorts (Moon and Lee, 2004). Samsung Heavy Industries, founded in 1974, is one of the largest shipbuilders in the world and produces oil drillers, cranes, and control trips for ships. Samsung Petrochemicals, established in the same year, also had successes with heavy industry and chemical production. Samsung Engineering, established in 1970, has become a leading manufacturer of machinery with a significant international presence and has completed projects in 38 countries, including power plants, natural gas terminals, and desalination facilities (Chang, 2006). However, the electronics branch of the company was by far the most successful in terms of climbing the technological ladder and leading Samsung's export crusade around the world.

FIGURE A1: SAMSUNG'S ECONOMIC EMPIRE



Note: Year in parenthesis indicates the year the affiliate was incorporated. Information from Samsung's official website.

During the 1970s, Samsung Electronics became a major supplier for foreign original equipment manufacturers (OEMs), especially Japanese and American firms such as JC Penney, Sears Roebuck, GTE, Toshiba, IBM, Hewlett-Packard, and RCA (Kim, 1997). Samsung was able to supply electronic parts at a low cost. Through these partnerships, Samsung gradually accumulated the technological know-how in the industry.

In the 1980s, after becoming highly successful in the export of electronic parts to OEMs, Samsung moved aggressively into the semiconductor industry and started the push toward the technological frontier. In particular, the 1983 semiconductor promotion law helped launch Samsung's ambitious push into the semiconductor industry. By 1984, Samsung announced the development of 64K DRAM technology and moved into the 256K DRAM production in just a few years. However, by 1985, the international semiconductor market suffered from overproduction and low prices, causing many producers, such as Intel and Japanese firms, to scale back from the market. Thanks to government support, Samsung aggressively increased capacity despite the market price drop (Kim, 1996). By 1993, Samsung produced more than 10 percent of the world's DRAM equipment, despite having close to zero market share only the decade before. In addition, by 1992, semiconductors became the largest export product of Korea, overtaking automobiles, textiles, and other manufactured goods (Kim, 1997).

By the late 2010s, Samsung and its affiliates accounted for around 20 percent of South Korea's total stock market value, 15 percent of its GDP (Ullah, 2017), and 20 percent of its exports (Hermitanio, 2019).

TSMC (Taiwan Province of China)

In 1987, Morris Chang, a former VP of Texas Instruments, founded the Taiwan Semiconductor Manufacturing Company (TSMC) with help from the government research institute ITRI and Dutch technology company Phillips. TSMC became the world's first dedicated semiconductor foundry and became a major player in the field, leading the technology frontier and accounting for 41 percent of the global foundry market by 2000 (Hsieh et al, 2002). By 2017, TSMC overtook Intel as the world's largest semiconductor manufacturer (Culpan, 2017).

Unlike Samsung, TSMC has not pursued diversification after its success in the semiconductor sector. Instead, it has maintained a sharp focus specializing in this single sector, maintaining its technological edge.

TSMC remains the world's most valuable semiconductor company, with a market valuation of 255 billion US dollars (Nellis and Shepardson, 2020). It is also the world's most advanced contract chip manufacturer, producing semiconductors for Apple, Huawei, Qualcomm, Nvidia, and over 400 other leading technology firms. Around half of the world's outsourced chip manufacturing is made by TSMC. TSMC became listed in Taiwan Province of

China in 1994 and on the New York Stock Exchange in 1997. It accounts for around one-third of Taiwan Province of China's benchmark index (Barrett, 2020).

Hitachi (Japan)

Founded in 1910 during Meiji Era, Hitachi played a crucial role in the early industrialization of the Japanese Empire. Before the onset of WWII, Hitachi has already emerged as a major zaibatsu conglomerate in energy, mining, automobiles, and manufacturing activities (Okazaki, 2001).

In the post-WWII era, Hitachi reemerged as a major conglomerate. Starting in the 1950s, it entered into a close partnership with Japan Railways Group (JR), helping develop Japan's high-speed rail system (*shinkansen*). Hitachi supplied locomotive equipment, signaling system, and much of the electronics technology (Gomersall, 2005). This relationship helped Hitachi become a domestic leader in the information technology and later computer fields (Kuwahara et al., 1989).

Hitachi was one of five companies in Japan's push into the semiconductor industry in 1976 (Callon, 1995). Thanks partly to government support and despite substantial political turnover (Table A3), it became a major international semiconductor firm. In 2003, it bought out IBM's hard disk business, making it one of the largest storage technology companies in the world (Hitachi, 2003).

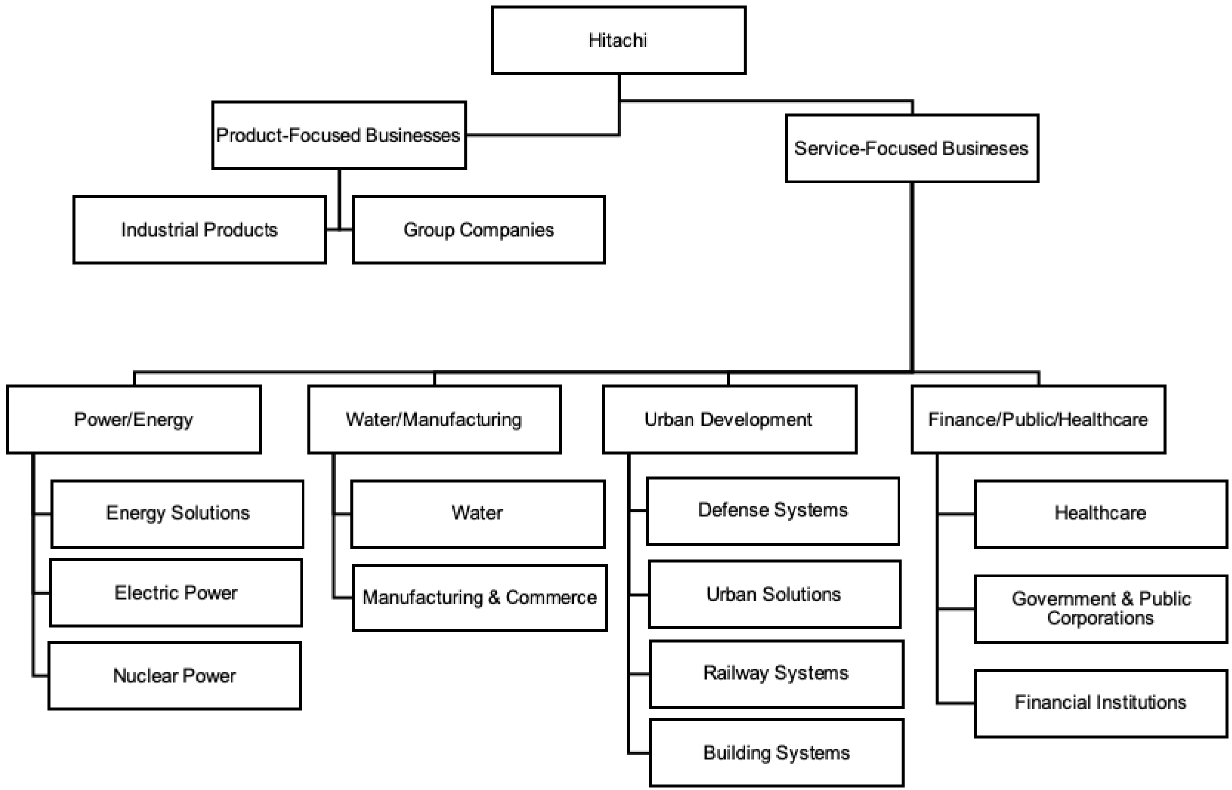
While Hitachi's business model met challenges in the late 2000s, the firm is currently the 9th largest company in the world. Fortunes ranked it as 102 largest in the world, with an annual revenue of 85.5 billion US dollars and close to 300,000 employees (Fortune, 2020). The company is a large conglomerate (Figure A2) spanning energy, manufacturing, finance, healthcare, and transportation (Hitachi, 2016).

TABLE A2. PRIME MINISTERS OF JAPAN (1976-2020)

Term	Name	Political Party
1976 – 1978	Takeo Fukuda	Liberal Democratic Party (LDP)
1978 – 1980	Masayoshi Ohira	Liberal Democratic Party (LDP)
1980 – 1982	Zenko Suzuki	Liberal Democratic Party (LDP)
1982 – 1987	Yusuhiro Nakasone	Liberal Democratic Party (LDP)
1987 – 1989	Noboru Takeshita	Liberal Democratic Party (LDP)
1989	Sosuke Uno	Liberal Democratic Party (LDP)
1989 – 1991	Toshiki Kaifu	Liberal Democratic Party (LDP)
1991 – 1993	Kiichi Miyazawa	Liberal Democratic Party (LDP)
1993 – 1994	Morihiro Hosokawa	Japan New Party (JNP)
1994	Tsutomu Hata	Japan Renewal Party (JRP)
1994 – 1996	Tomiichi Murayama	Japan Socialist Party (JSP)
1996 – 1998	Ryutaro Hashimoto	Liberal Democratic Party (LDP)
1998 – 2000	Keizo Obuchi	Liberal Democratic Party (LDP)
2000 – 2001	Yoshiro Mori	Liberal Democratic Party (LDP)
2001 – 2006	Junichiro Koizumi	Liberal Democratic Party (LDP)
2006 – 2007	Shinzo Abe	Liberal Democratic Party (LDP)
2007 – 2008	Yasuo Fukuda	Liberal Democratic Party (LDP)
2008 – 2009	Taro Aso	Liberal Democratic Party (LDP)
2009 – 2010	Yukio Hatoyama	Democratic Party of Japan (DPJ)
2010 – 2011	Naoto Kan	Democratic Party of Japan (DPJ)
2011 – 2012	Yoshihiko Noda	Democratic Party of Japan (DPJ)
2012 – 2020	Shinzo Abe	Liberal Democratic Party (LDP)
2020 -	Yoshihide Suga	Liberal Democratic Party (LDP)

Source: Government of Japan.

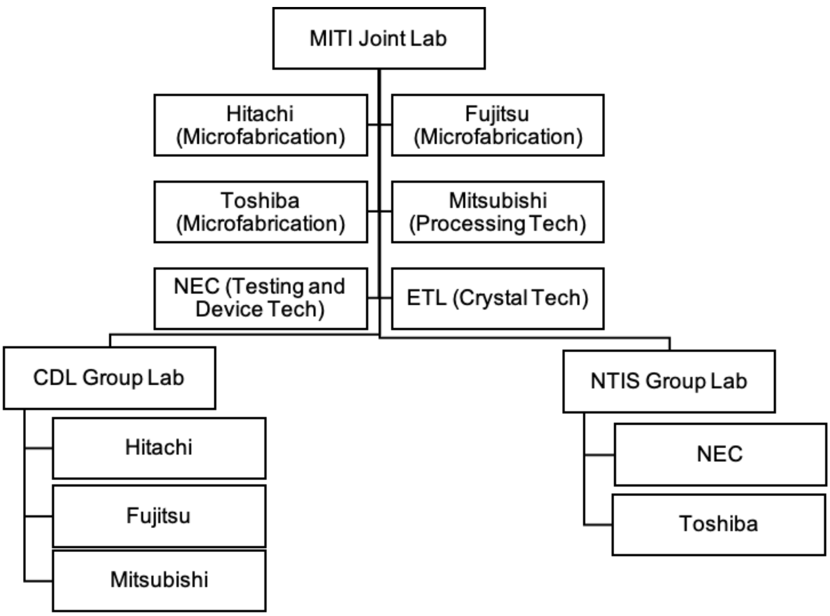
Figure A2. Hitachi Structure since its 2016 Reorganization



Source: Based on information from Hitachi (2016).

To jumpstart the semiconductor industry, in the late 1970s, MITI spearheaded the research consortium consisting of a joint lab and two group labs. The joint lab involved all five companies, Hitachi, NEC, Fujitsu, Toshiba, and Mitsubishi, and MITI's in-house research center, the Electro-Technical Laboratory (ETL). Each of the participants in the joint lab was assigned an area of basic research in microfabrication, semiconductor devices, semiconductor manufacturing processes, and silicon crystals and wafers. The group labs consisted of the Computer Development Laboratories (CDL) of Hitachi, Fujitsu, and Mitsubishi, and the NEC-Toshiba Information Systems (NTIS) lab of NEC and Toshiba (Figure A3). The group labs had their own specific collaboration projects (Callon, 1995).

Figure A3. Organization of Japan's VLSI Research Consortium



Source: Based on information from Sakabibara (1983) and Callon (1995)

CSM (Singapore)

Semiconductor MNCs have had a long history operating in Singapore. As early as 1969, the US-based National Semiconductor and Fairchild Semiconductor set up production facilities. Encouraged by political stability (Table A4), by the mid-1970s, other MNCs such as Texas Instruments, Motorola, Signetics, Radio Company of America (RCA), Intel, American Microsystems, and Mostek had started production activities (Rasiah and Shan, 2016). After the country's focus shifted toward creating linkages with domestic firms, SGS Thompson set up a new production facility in 1985 and HP set up its first overseas wafer fabrication in 1987 (Matthews, 1999).

In 1987, the state-owned Singapore Technology Group (STG) entered into a technology transfer agreement with US-based Sierra Semiconductor company to set up a new semiconductor smanufacturer, the Chartered Semiconductor. Sierra agreed to transfer its 3.0-micron process technology and train over 100 Singaporean technical staff. In exchange, the new semiconductor manufacturer would supply Sierra Semiconductor and National Semiconductor, offering cheap wafers for their products. However, when National Semiconductor dropped out of the supply agreement, the STG faced a crisis. STG decided to buy out shares of the company from Sierra and split Chartered into a manufacturing branch (CSM) and an integrated circuit design company (Tritech) (Matthew, 1999).

Table A3. Prime Ministers of Singapore

Term	Prime Minister	In Office	Party
1	Lee Kuan Yew	1959 – 1990	People's Action Party
2	Goh Chok Tong	1990 – 2004	People's Action Party
3	Lee Hsien Loong	2004 -	People's Action Party

Source: Government of Singapore.

By the late 1990s, Chartered Semiconductor Manufacturing (CSM) was already one of the major competitors to TSMC and competed with other semiconductor MNCs based in Singapore as one of the city-state's only domestic champions. In 2000, CSM had a revenue of 1 billion dollars and five foundries producing state-of-the-art chips for products in Singapore and the Asia Pacific region (SEC, 2006). However, despite its meteoric rise in the 1980s and 1990s, CSM encountered difficulties in the 2000s. In 2009, CSM was sold off to an Abu Dhabi based company for 1.8 billion US dollars (Brown, 2009).