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The industrial policy experience of the electronics industry in Malaysia

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Abstract: Despite the use of industrial policies to stimulate economic growth by several successful developers, latecomers have faced mixed experiences. Hence, this paper analyses the industrial policy experience of the electronics industry in Malaysia. A blend of institutions have guided technological upgrading in the industry, especially in the state of Penang. Smooth co-ordination between the state government, multinational corporations, national firms, and the federal government helped stimulate technological upgrading in Penang. However, the lack of a critical mass of human capital and support from research and development organizations has discouraged the transformation of firms in the industry to the globe's technology frontier.

Keywords: industrial policy, institutions, electronics industry, Malaysia

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1 Introduction

Malaysia is among the countries that shifted its industrial focus from import-oriented to export-oriented industrialization since the enactment of the investment Incentives Act of 1968 (Malaysia 1971). Foreign direct investment (FDI) figured prominently in the New Economic Policy (NEP), which was launched through the Second Malaysia Plan in 1971 (Malaysia 1971). Since 1972, Free Trade Zones (FTZ) were opened to attract export-oriented FDI in light manufacturing activities to expand employment opportunities following the identification of manufacturing as the engine of growth in the Second Malaysia Plan of 1971-75. Firms seeking to locate in areas that required specific infrastructure that could not be provided in FTZs were offered Licensed Manufacturing Warehouse (LMW) status. As early as the 1970s, giant Multinational Corporations (MNCs) consequently relocated textile and electronics operations in Malaysia.

While unemployment levels in Peninsular Malaysia fell as a consequence of FDI inflows, the nature of demand facing electronics manufacturing, which is characterized by short boom-bust cycles, meant that retrenchments were also common whenever economic downswings hit the industry (Rasiah 1988). Nevertheless, employment, exports, and manufacturing value-added in the electrical-electronics industry expanded sharply in trend terms until 2000 to become the leading manufacturing industry in Malaysia. From the initial focus on investment and employment, the government earmarked the electrical-electronics industry as a strategic industry since 1986 to spearhead the industrial transformation of the country. The 1985-86 economic crisis, when GDP growth hit negative figures, delayed the introduction of technological upgrade policies, which were introduced starting in 1991 (Malaysia 1991a). The Action Plan for Industrial Technology Development became the pivot[1] to lead Malaysia's transformation into a developed country by 2020. Major meso-organizations targeted at solving collective action problems were launched to spearhead the transformation.

However, chaotic co-ordination amongst technological deepening, poorly implemented industrial plans, and the lack of strong human capital development policies, including weak policies on schools and universities, and the low utilization of human capital endowed with tacit knowledge from abroad, discouraged structural change from low to high value-added activities in the industry. While a massive inflow of FDI from East Asia since the late 1980s and exchange rate depreciation since 1997 stimulated strong expansion of employment, exports, and value added activities, the contribution of the industry in the national economy has gradually declined since 2000. The provision of grants particularly since 2005 has helped stimulate some functional upgrading into chip design, wafer fabrication, and Research and Development (R&D). This development has stimulated a positive trade balance in the industry after 2005. However, such initiatives have not been successful in driving Malaysia's ability to compete globally on the technological frontier.

Thus, this paper seeks to examine government initiatives to promote the electrical-electronics industry, including the objectives and how they translated into firm-level technological advancement. The electrical-electronics industry was selected for this purpose, as it has been the most important manufacturing industry in Malaysia since the late 1980s. In so doing, we seek to deploy some robust methodology to assess technological catch up to evaluate the extent of success Malaysia's industrial policies have enjoyed in spearheading firm-level technological change.

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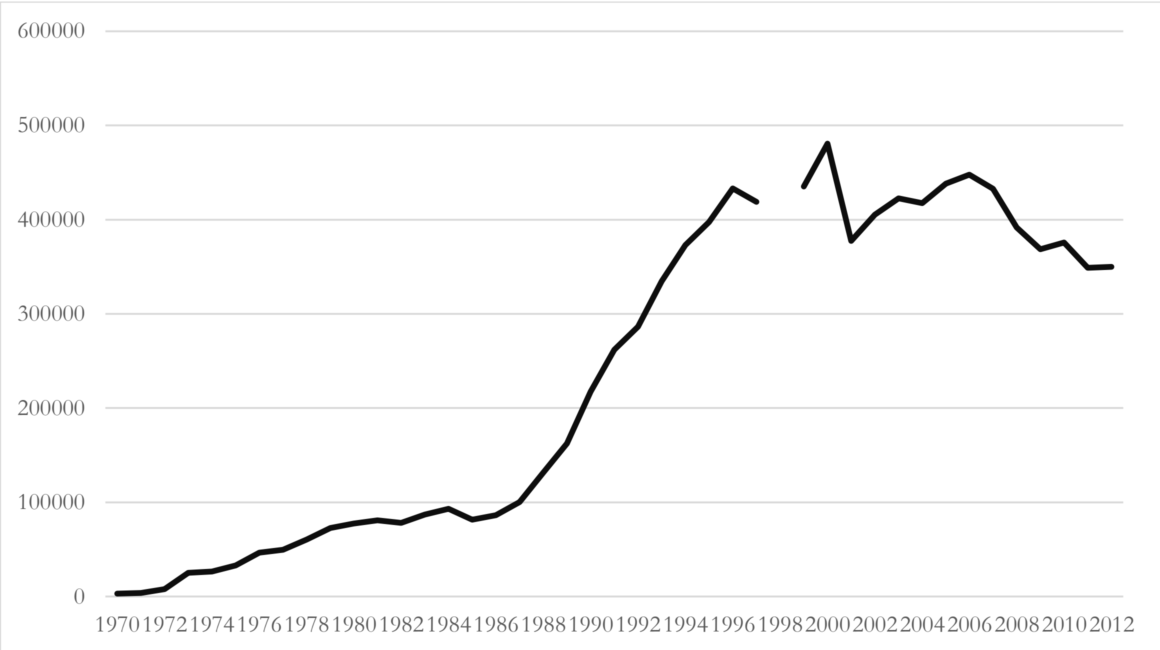
[1] This was contained in the government blueprint, The Way Forward (Malaysia 1991b).

2 Importance of the electrical-electronics industry

The electrical-electronics industry began growing rapidly in Malaysia following the opening of FTZs in 1972 (Lim 1978; Rasiah 1988). Two major waves took place in the industry in 1972-74 and 1988-93 respectively, and a slight structural shift occurred starting in 2005 (Rasiah 2010). Whereas the two major waves were characterized by a significant accumulation of fixed assets from FDI inflows, the third arose from the relocation of chip design, wafer fabrication, and supportive R&D activities against a background where the industry has largely faced downsizing.

Except for the cyclical fluctuations associated with the industry-wide boom-bust cycles (Rasiah 1988), employment rose in the electrical-electronics industry in trend terms from 1970 until 1984 (see Figure 1). The severe industry-wide crisis that followed in 1984-85 resulted in a fall in employment. After the shakeout, employment grew sharply, especially since 1988 following a massive inflow of FDI from Japan, Taiwan, South Korea, and Singapore. This expansion continued over the Asian financial crisis in 1997-2000, as the fallen Ringgit lowered production costs in the country. The slight fall in 1997 was a consequence of firms' taking advantage of privileges given to firms to retrench workers, as it was not clear how the crisis would pan out when it first struck in 1997. However, since its peak of 2000, employment in the industry has gradually fallen in trend terms.

Figure 1: Employment, electrical-electronics industry, Malaysia (1970-2012)

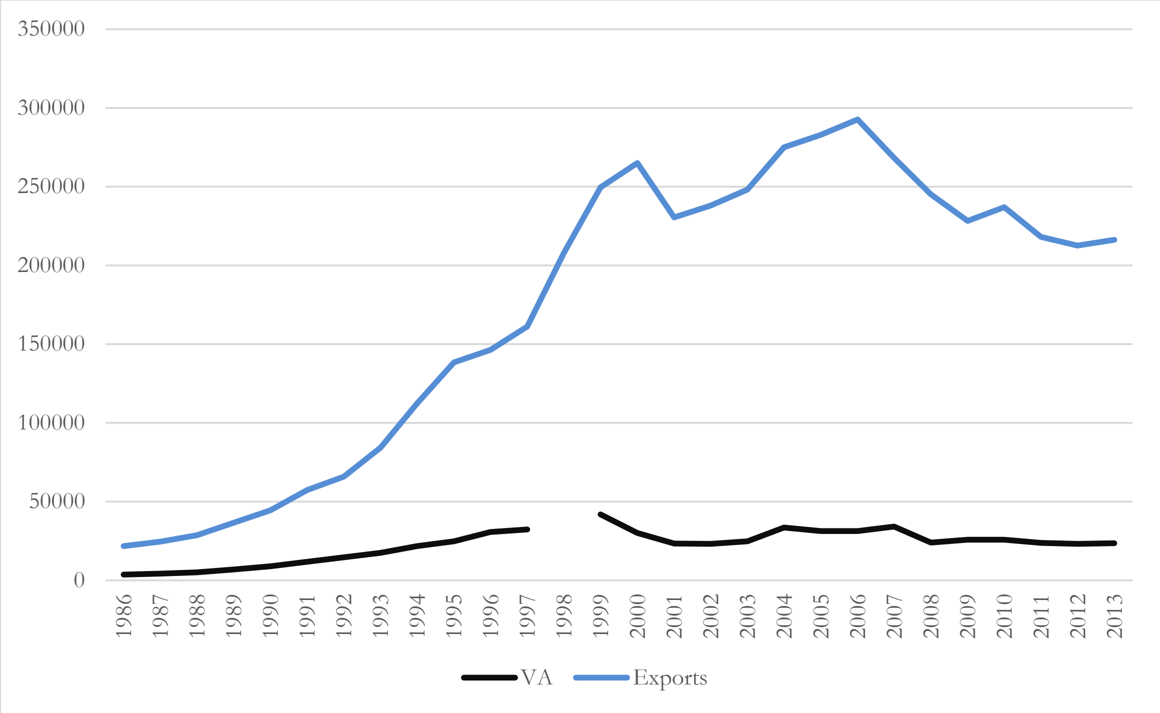


Source: Author's compilation based on data obtained from Malaysia, Department of Statistics.

To obtain an informed analysis of the impact of industrial policy on the electronics industry in Malaysia, we confine the presentation of data to the period from 1986 when the first Industrial Master Plan was launched (Malaysia 1986). However, following the severe downturn that affected the industry in 1984-85, the plan relaxed all pressures on upgrades so as not to scare away existing firms. The industry expanded sharply again from 1988 until 2000 as massive FDI inflows were recorded from Japan, Taiwan, South Korea, and Singapore. Value-added activities and exports from the industry rose strongly until 2000 but began to fall thereafter in trend terms (see Figures 2 and 3). The industry's share of manufacturing value-added activities rose to its peak of 37.2 per cent in 1999 and manufactured exports to its summit of 72.5 per cent in 2000. Against the grain of macroeconomic developments, the Asian financial crisis boosted electronics exports, which was caused by falling production costs from a sharply fallen Ringgit, and a rapidly growing American market (Rasiah et al. 2014).

However, exports, value-added activities, and employment began to slow down after 2000, as the industry expanded strongly in China and Vietnam until a sharp decline in 2008 accompanied the global financial crisis, which affected exports to the major markets of the United States and Europe (see Figures 1-3). Thus, the industry's share in manufacturing value-added activities and exports fell to 14.9 per cent and 48.0 per cent respectively in 2013.

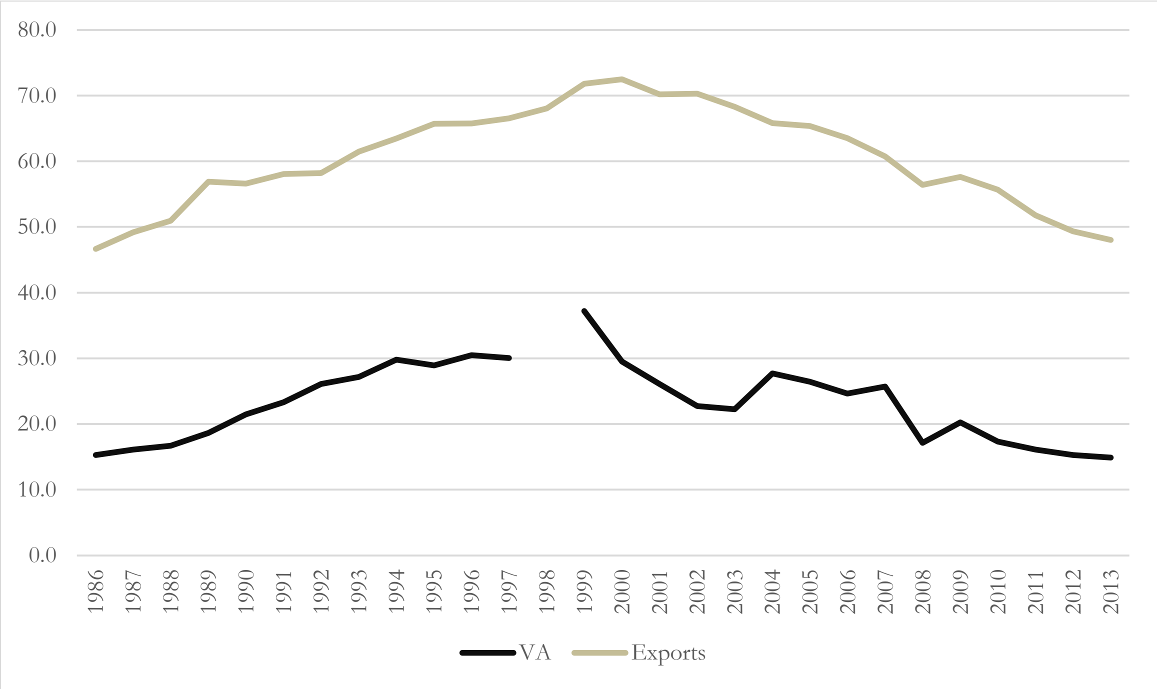
Figure 2: Exports and value-added activities in electrical-electronics industry, Malaysia (1986-2013)



Note: VA=Value added.

Source: Author's compilation based on data obtained from Malaysia, Department of Statistics.

Figure 3: Contribution of electrical-electronics to manufacturing, Malaysia (1986-2013)



Note: MYR millions in 2005 prices; VA=value added.

Source: Author's compilation based on Bank Negara Malaysia (2015), Malaysia, Department of Statistics.

While one would expect the share of particular industries in an economy to rise and fall as the economy matures, even when productivity continues to rise, this has not been the experience of the electrical-electronics industry in Malaysia.

3 Theoretical considerations

Industrial policy has been defined in many ways by various authors. The common one defines industrial policy as a policy or a set of policies targeted at the expansion of industry in general, and manufacturing in particular (Kaldor 1967). While structural economists, such as Young (1928) and Kaldor (1967), focused on the differentiating characteristics of industrialization and its impact on the division of labour and economic expansion, they did not analyse specifically the technological deepening issues. Chenery et al. (1986) and later Lall (1992) attempted to do this but confined structural change to categorizations by capital goods, consumer durables, intermediate goods, raw materials and, heavy, medium, and light industries. Such classifications do not address innovation and technology directly.

The transformation of production into different stages and the evolution of embodied knowledge in which innovation depth has transcended the boundary of the nature and type of goods and services means that it no longer matters whether countries experience structural transformation from a specialization in consumer and intermediate goods to capital goods, or from low and medium technology to high technology goods. For example, Taiwan and Singapore show a greater specialization in components and intermediate goods than Malaysia does but the former two are technologically far superior to the latter, which is reflected in their respective value-added activities. Hence, a successful industrial policy should be viewed as an exercise in which it successfully stimulates sustainable economic transformation from low to high value-added activities.

Marx (1957), Veblen (1915), and Schumpeter (1943, 1961) created the foundations for the real assessment of technology through the unbundling of the black box by Rosenberg (1976, 1982), which led to a plethora of work defining technological capabilities (Bell et al. 1984; Dahlman 1984; Lall 1992).

The catch-up literature, which has its historical origins in Marx's (1957) notion of capitalist integration and accumulation, was expounded further through the work of Veblen (1915), Gerschenkron (1952), and Abramowitz (1956). These works gave rise to the developmental functions of the state, which goes beyond the regulatory role of the state. The empirical foundations of the developmental state articulating the active role of government in stimulating industrial structural change can be found in works explaining industrial catch up by Japan (Johnson 1982), Korea (Amsden 1989), and Taiwan (Wade 1990). However, while Amsden (1989) and Amsden and Chu (2003) provided explicit accounts of catching up in particular industries, Johnson (1982) and Wade (1990) did not present the empirical evidence on innovation and technology against the particular industrial policy pursued in Japan and Taiwan respectively.

Hence, the work of Rosenberg (1982), Bell et al. (1984), Dahlman (1984), and Lall (1992) becomes important in attempting to examine the evolution of technological capabilities in developing economies. It is also important to see how government-initiated institutional change through industrial policies affected firm-level technological upgrading in particular countries.

Figueiredo (2001), Rasiah (2003), Ariffin and Figueiredo (2004), and Wignaraja (2002) attempted to examine firm-level technological capabilities but their focus was overly confined to the firm-level and did not look at the broader perspective. Although Ariffin and Figeuredo (2004) attempted to analyse upgrading over time, their attempt did not locate their observed firms against the lead firm at the globe's technology frontier.

Meanwhile, Rasiah and Myint's (2013) attempt was limited to demonstrating the possibility of technological upgrading even in the most underdeveloped locations rather than to relate such developments to industrial policies. Rasiah (2004) attempted to link technological capabilities with institutional support but the approach included too many institutions to distinguish the importance of industrial policy. Hence, this paper seeks to examine the evolution of technological capabilities against the particular type of industrial policy by using the electronics industry as a case study. The confinement of analysis specifically to the electronics industry and to Malaysia is consistent with the evolutionary argument that institutional change and technological change are industry, location, and time specific (Nelson 2008).

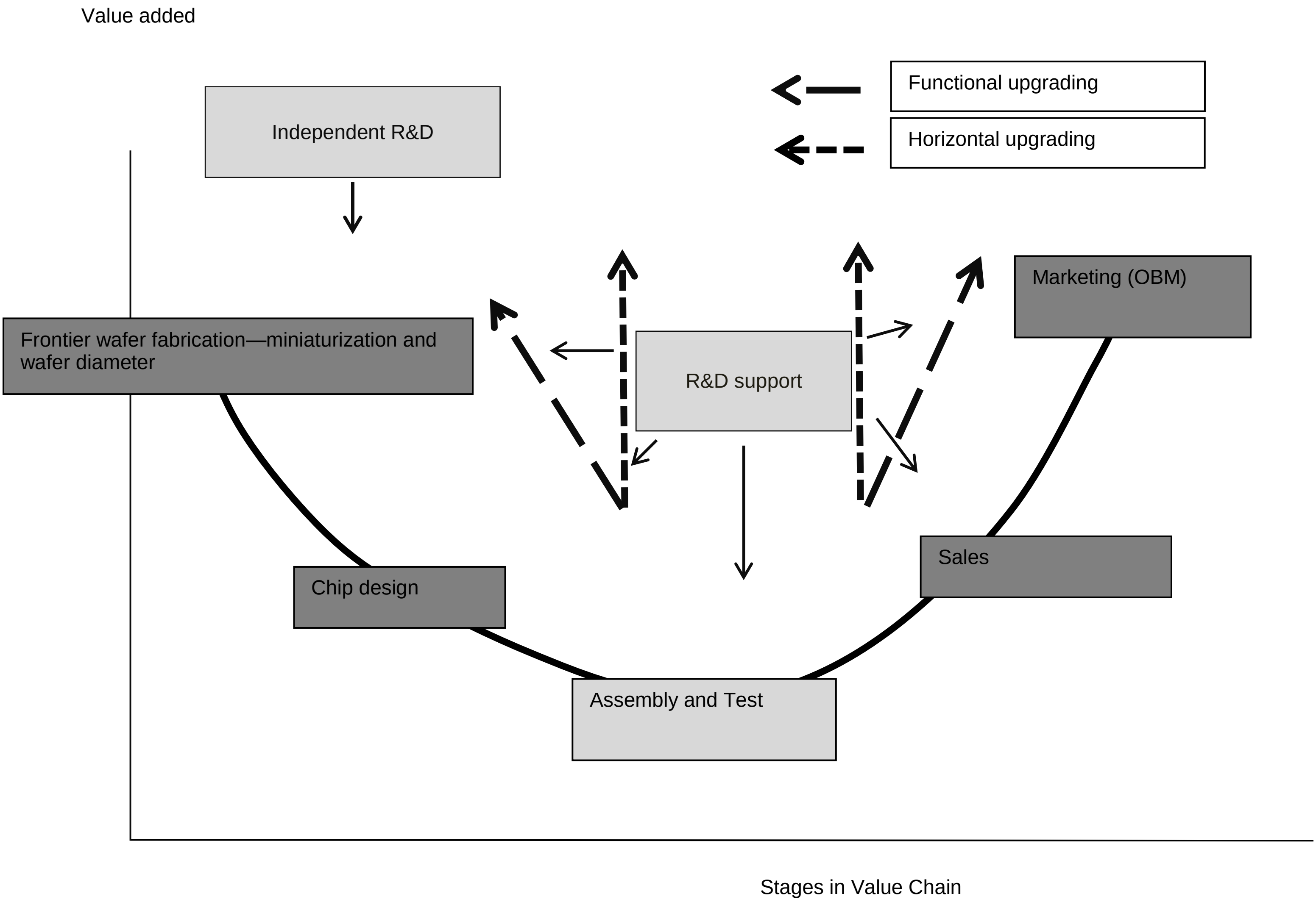
Taking these accounts, we analyse the application of industrial policy in this paper by first examining the instruments used to promote industrialization, its impact on the share of manufacturing in the national economy, industrial structural change experienced in the economy (value added, employment, and exports), and most importantly, technological upgrading.

4 Methodology and data

The methodology deployed in this study is based on examining changes in value-added activities, employment, exports of electrical and electronics goods in absolute terms and as a share of manufacturing, and an assessment of changes in technological capabilities in the electronics industry since 1970 using firm-level surveys. Because of the difficulty in attempting to evaluate changes in technological capabilities, especially as one gets deep into history, the latter is confined to the semiconductor industry, which is the largest value-added component of the electronics industry in Malaysia. The meta-physical datasets are drawn from government compiled aggregate statistics, and a firm-level survey, while the qualitative information is drawn from interviews with company officials.

The analytic framework for analysing technological upgrading in the semiconductor industry is shown in Figure 4. The first dimension of technological upgrading follows the functional elements of catch up in which semiconductor firms integrate front- and back-end operations, while some relocate or upgrade to participate in R&D, IC design, and wafer fabrication. The former can be referred to as functional integration and the latter as functional upgrading (see Figure 4). Integration activities are not classified as functional upgrading if they are limited to the merging of lower value-added activities—e.g. the addition of assembly to test activities in wafer fabrication. Instead, they are referred to as functional integration without upgrading.

Figure 4: Value chain of ICs (2014)



Source: Diagram created by author.

The second dimension of technological upgrading follows from the deepening of the same functional activities as semiconductor firms absorb best practices. These include cutting edge inventory and quality control systems, and introduction of adaptive engineering and R&D support to upgrade particular functional categories of activities to raise plant-level productivity that entrepreneurs can easily undertake. Training and skills development ensure high level of competency among the workers to perform continuous improvement at the workplace.

Combining both dimensions of technological upgrading, it is possible to define the technological depth of semiconductor firms by process and product technologies. Hence, it is possible to evaluate the success of industrial policy by first examining if firm-level upgrading took place and if it was influenced by industrial policy, or if a lack of such upgrades was a consequence of the absence of dynamic industrial policies.

To ensure that the sample drawn is representative of the population, we took a stratified random sample by ownership (Table 1). Of the 39 semiconductor firms in Malaysia in 2014, six were Malaysian owned. Since the study required firm visits to explain adequately to the respondents the typology used for the study, the question of missing values did not arise. Indeed, we managed to get 100 per cent of the sampled firms to respond to the study.

Table 1: Sampled semiconductor firms, Malaysia, 2014

	Total	Foreign	National
Sampled firms	25	21	4
Total (%)	100	84	16

Source: Rasiah (2015).

Table 2 shows the template used to locate the sampled semiconductor firms by technological capabilities. Whereas we refer to technology embodied in human resources (HR) as competencies, we classify process and product as capabilities. The classification criteria for the different activities are based on interviews conducted with the leading firms in the industry (Rasiah et al. 2015).

Table 2: Technological competence and capability, semiconductor firms, Malaysia, 2014

		Human Resource	Process	Product
1	Simple activities	On the job and in-house training	Dated machinery with simple inventory control techniques	Assembly of components
2	Minor improvements	In-house training and performance awards	Advanced machinery, layouts and problem solving	Precision engineering
3	Major improvements	Extensive focus on training and retraining; staff with training responsibility	Cutting edge inventory control techniques, SPC, JIT, and TPM	Cutting edge quality control systems (QCC, TQM) with OEM capability
4	Engineering	Focus on engineers for absorbing best practices	Process, layout, equipment, and technique adaptation	Product adaptation
5	Early R&D	Focus on engineers for process and product development activities	Process development	Product development with ODM capability
6	Mature R&D	Focus on specialized R&D engineers	New process development	New product development some with OBM capability
7	Frontier technology	Strong links between R&D engineers and frontier research in universities	Process development to accommodate frontier products	Frontier products

Notes: SPC – statistical process control; JIT – just in time; TPM – total preventive maintenance; QCC – quality control circles; TQM – total quality management; OEM – original equipment manufacturing; ODM – original design manufacturing; OBM – original brand manufacturing.

Source: Rasiah (2015).

5 Promotion of electronics manufacturing

Government promotion of manufacturing in Malaysia was initiated through the Pioneer Industry Ordinance (PIO) of 1958, which sought to stimulate inward-oriented manufacturing targeted at substituting imports. It was during this time that Malaysia's first electronic-electrical firms were started when Matsushita Electric relocated its manufacture of electrical goods in 1965. However, because of the small domestic market, the screwdriver industries that were begun during this phase stagnated by 1965, by which time the Malaysian Industrial Development Authority (MIDA) was launched to spearhead industrial promotion. The conditions for export orientation were started when the Investment Incentives Act was promulgated in 1968. Labour laws were tightened to restrict the role of trade unions through amendments to the Industrial Relations Act in 1967. Hence, since the late 1960s, export-oriented foreign multi-national corporations relocated assembly and processing activities as they were seeking to relocate labour-intensive operations to countries endowed with surplus of trainable labour (Scibberas 1977; Lim 1978).

Over the period 1986-2015, Malaysia experienced the introduction of three industrial master plans, and two rounds of export-orientation. The first period of promotion following the PIO saw virtually no expansion of electronics manufacturing because of the small domestic market and because the state confined its role strictly to the regulatory function of approving foreign investment applications and incentives targeted at supplying final goods to the domestic market. Significant expansion in electronics manufacturing only began in 1971, following the launch of export-oriented manufacturing.

6 First-round export-orientation

Electronics manufacturing expanded sharply in Malaysia only after the introduction of export-oriented manufacturing in 1971, which was promoted through the second Malaysia Plan of 1971-75, and the opening of FTZs and LMWs in 1972. The prime objective of these zones was to attract FDI to generate jobs, which the government managed through the development of export processing zones to house giant firms from abroad engaged in light manufacturing activities. To facilitate the inflow of FDI, the government offered financial incentives (tax and tariff operations through tax holidays and investment tax credits for a period of five years) to firms locating at FTZs and LMWs, which were renewable for another five years.

While economic restructuring by ethnicity became the prime focus of the NEP, the export-oriented manufacturing sector was spared from such requirements as incentives, including tax exemptions and tariff-free operations, were offered to firms on the basis of investment and employment generated (Malaysia 1971). The Philippines became the main competitor to Malaysia in the 1970s, as it had a much larger English-speaking labour reserve that was willing to work for low wages. China and the transition economies of Indo-China and Myanmar were not open to capitalist organization until 1978 and the late 1980s respectively. South Korea, Taiwan, and Indonesia also did not pose serious competition to attract FDI as these countries in the 1970s had placed stronger emphasis on national firms. Malaysia's ability to play the regulatory role by simplifying approvals and offering security and stability at the FTZs gave it an edge over the Philippines.

Hence, the FTZs and LMWs began to enjoy a massive influx of foreign electronics MNCs. Clarion and National Semiconductor were the earliest export-oriented multinationals in Malaysia when they built their factories at the Bayan Lepas Free Trade Zone in Penang in 1971. By the mid-1970s, Intel, Advanced Micro Devices, Texas Instruments, Hitachi, Motorola, HP, and Siemens (Litronix) had relocated massive assembly operations to Malaysia. While Motorola and Siemens have since sold their semiconductor plants in Malaysia to Freescale and Qimonda respectively, Hitachi transformed into Renesas, and National Semiconductor acquired the brand name of Fairchild. Most foreign semiconductor firms that relocated operations in the 1970s have retained operations in Malaysia. Other semiconductor firms to relocate operations to Malaysia since 1990 include Integrated Device Technology, Infineon, ST Microelectronics, Unisem, Carsem, Globetronics, Silterra, X-Fab, Avago, Alterra, Osram, and Onn Semiconductor. The expansion in electronics production was so swift that the industry had become the largest generator of manufacturing employment, value-added activities, and exports in Malaysia by the late 1980s (Rasiah 2010: Figure 3). However, most consumer electronics firms left Malaysia by the late 1990s owing to a tightening labour market from the mid-1990s as a surplus of FDI caused economic overheating.

Because the government also had in place an import-substitution sector that supplied the domestic sector, it stipulated originally that firms locating at FTZs and LMWs export all their items irrespective of the share of inputs enjoyed domestically. Since 1986, these firms were allowed to sell 20 per cent of their output in the principal customs area of Malaysia when attempts were made to promote domestic linkages. The provision of excellent basic infrastructure, security, political stability, and the quick handling of related issues helped make the FTZs and LMWs safe production bases in the global division of labour of foreign MNCs.

While the first-round export-orientation policies proved successful, it did not meet the key objective of industrial policy, which is to stimulate the structural transformation of the electronics industry from low to high value-added activities. In fact, Singapore managed to attract Hewlett Packard to relocate some aspects of wafer fabrication in the late 1980s only because Malaysia refused to provide capitalization grants upfront (Rasiah 1989). Hence, while manufacturing was identified as the engine of growth and incentives were offered to attract MNCs since 1971, until the early 1990s, the government did not attempt to introduce the active instruments of industrial policy to promote technological deepening.

As a consequence, electronics manufacturing faced enormous pressure by the end of the first-round of export-orientation (EO) from two fronts. On the first front, the government had begun to favour national capital over foreign capital in the provision of incentives following the introduction of its heavy industrialization programme in 1981. Hence, the government began delaying efforts by MNCs such as, Advanced Manufacturing Devices, Intel, and Motorola, to have their incentives renewed (Rasiah 1993). On the second front, the semiconductor industry began facing a severe cyclical crisis. Overproduction and cutthroat competition caused major shakeouts in the industry over the period 1984-87 (Rasiah 1989). A few MNCs with operations in Malaysia were acquired by other firms—e.g. Mostek by Thomson CSF, which was eventually sold to International Device Technology. Malaysia was also experiencing a severe balance of payments crisis as the prices of primary commodities had fallen considerably in the mid-1980s in the face of mounting external loans given in the hopes of building infrastructure (Jomo 1990).

Nevertheless, over the period 1971-80, the electrical-electronics industry achieved the objectives expected of government policy, which was to attract export-oriented FDI as employment rose in trend terms (see Figure 1). Indeed, Penang's rapid growth is very much a consequence of FDI inflows into the FTZs and LMWs. The unemployment rate fell from 8.1 per cent in 1971 to 4.0 per cent in 1980. Employment fell in the crisis years of 1985-87 but rose sharply again since 1987 to 2.5 per cent in 1998. The only developmental role played by the state in this phase was to approach directly potential investors among MNCs from the United States, Japan, and Europe to relocate in Malaysia, and to develop actively the basic infrastructure, including the FTZs and LMWs. Qualifying firms enjoyed financial incentives, which the state performed through its regulatory function.

7 Second-round export-orientation

The second round of export-orientation can be traced to 1986, when the government resumed the active promotion of exporting firms. The first Industrial Master Plan (IMP1) was introduced in 1986 but because of the 1984-85 recession, the government targeted only the easily achievable milestones. A few developments assisted the rapid recovery and subsequent expansion of the electronics industry in Malaysia. While the production experience of more than a decade was useful when the cyclical recovery began in the industry in 1987, appreciation of the Yen, Won, the New Taiwan dollar, and the Singapore dollar following the Plaza Accord of 1985, and the withdrawal of the Generalized System of Preferences (GSP) in February 1988 (from Korea, Taiwan, Hong Kong, and Singapore) acted as a major driver of FDI outflow from these countries to the market economies of Southeast Asia (Rasiah 1989). Meanwhile, following negative GDP growth rates recorded in 1985-86, the Malaysian government devalued the Ringgit and extended the investment tax credits to electronics MNCs. Hence, until the early 1990s, the government returned to perform its largely regulatory role to stimulate FDI inflows in the electronics industry. The aggressive promotion of FDI inflows and push-driven FDI outflows from northeast Asian economies attracted again massive inflows of equipment and parts, industrial and commercial, and consumer electronics firms into Malaysia to push up exports from these industries (see Figure 5).

Although the government started Malaysian Institute of Microelectronics Systems (MIMOS) in 1985 to support the development of national semiconductor firms, it was not until 1991 that the government began promoting functional upgrading to stimulate the transformation of the industry to high value-added operations, such as wafer fabrication, chip design, and R&D, following the launch of the Action Plan for Industrial Technology Development (APITD). Silterra was conceived within the premises of MIMOS in 1995 and launched at Kulim High Tech Park in 2000 to fabricate wafers using the Taiwanese framework of buyer-supplier alliances. Meanwhile, Carsem, Unisem, and Globetronics emerged as private Malaysian firms with their managements dominated by former employees of foreign semiconductor MNCs in Malaysia. The government also extended the provision of grants to foreign firms in 2005, which helped attract wafer fabrication plants by Infineon, Onn Semiconductor, and Osram.

The First and Second Industrial Master Plans of 1996 and 2006 stepped up the focus on stimulating structural transformation from low to high value-added activities but the government's role did not shift much from regulatory to developmental (Malaysia 1996, 2006). There was a call for targeting financial incentives to capital-intensive and strategic industries in the IMP2 but that was stopped when the Asian financial crisis struck in 1997. Clustering was promoted in IMP2 and IMP3 but the regulatory instruments at the policy level did not differentiate between value chains, complementary buyer-supplier firms, or meso-organizations that were required to synergize promoted industries.

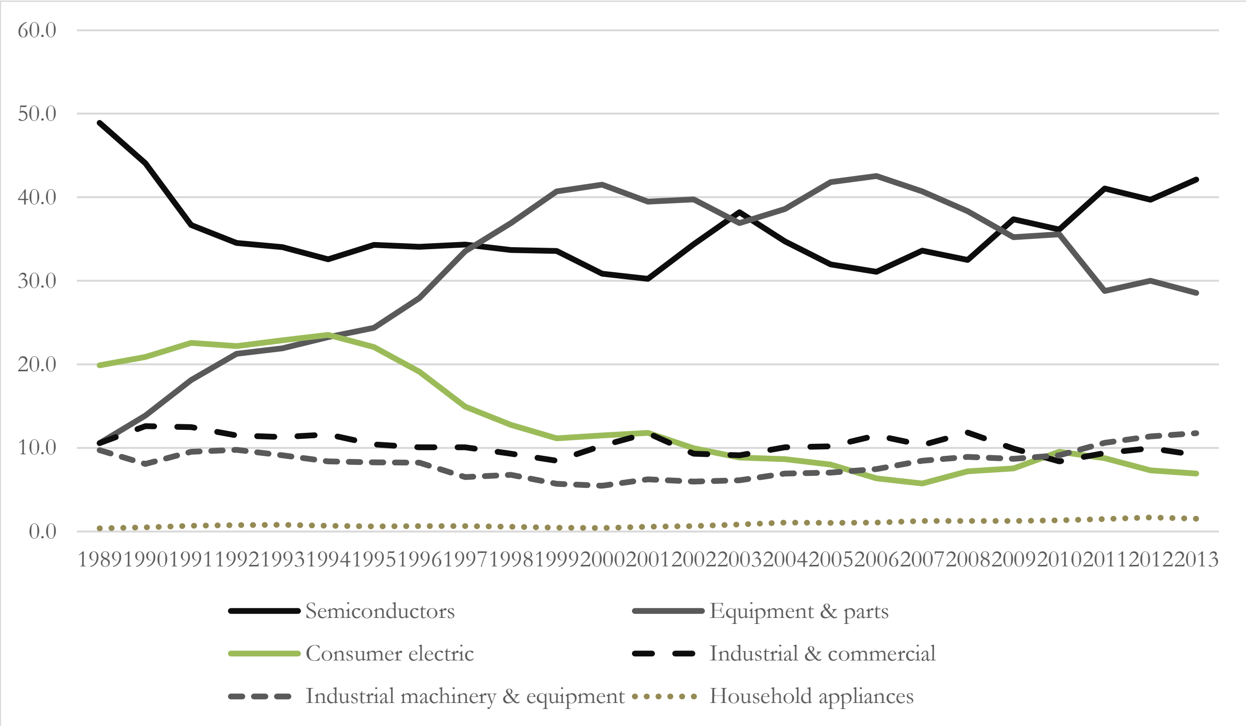
The government acquired VLSI in 1995 to initiate wafer fabrication similar to Taiwan but did not appoint leaders with the tacit and experiential knowledge of working in lead firms to orchestrate technological catch up the way Morris Chang engineered both the Hsinchu Science-based Industrial Park and Taiwan Semiconductor Manufacturing Corporation. The acquisition of VLSI technology offered the opportunity to skip stages in the technological ladder but lack of leaders with the ability to manage the process gave Silterra no opportunity to embark on a clear catch up path. Yet, Rasiah (1988, 2011) had demonstrated how crises have given opportunities for latecomer firms, such as Samsung Semiconductor and TSMC to catch up.

The fall in unemployment rates in Malaysia encouraged the government to stimulate technological upgrading from 1991. A wide range of meso-organizations were created to provide public goods and to solve collective action problems. However, political colouring in the creation and management of these organizations restricted their capacity to stimulate technological upgrading. Hence, while Korea and Taiwan successfully attracted their diaspora endowed with tacit and experiential knowledge to lead, including the management of science industrial parks and lead firms, Malaysians with such capabilities were overlooked. Examples of Malaysians overlooked include Loh Kin Wah, the managing director of Qimonda in 2008. Also, while 'carrots' were given to national firms during the Dr Mahathir regime, the 'stick' was never applied, and the replacements never proved capable because of the absence of strong tacit and experiential knowledge among the criteria in their appointments. The second Industrial Master Plan (IMP 2) of 1996 earmarked efforts to stimulate clustering, though its application was misdirected sectorally (Rasiah 1999). The instruments of technological deepening were not implemented because of the government's reluctance to offer grants to foreign and ethnic Chinese firms, demonstrating that the government developmental capacity was compromised by political considerations.

Although functional integration evolved strongly since 1990, it took place largely in the low value-added equipment and parts segment of the electrical-electronics industry (see Figure 5). Such integration actually led to functional downgrading. Both the IMP1 and the IMP2 failed to stimulate functional upgrading into higher value-added segments of the industry as the government neither offered the grants nor had in place effective human capital development policies to step up the supply of quality engineers and scientists. Indeed, Cheong et al. (2011) provided evidence to show that the poor quality of education in Malaysia has inhabited rapid economic transformation in the country. Without a critical mass of human capital, the increasing competition from China, Philippines, and Indonesia has forced imports of foreign labour, which helped keep wages from rising but also restricted technological upgrading. The consumer electronics segment of electronics manufacturing continued to decline as firms began to relocate operations to China, Philippines, Indonesia, and Vietnam (see Figure 5).

The government extended the provision of R&D grants to foreign electronics firms only from 2005, which helped attract the high value-added stages of wafer fabrication (e.g. Infineon, Onn Semiconductor, Osram); IC design (Intel, AMD, Freescale, Hitachi); and R&D (e.g. Intel, AMD, Hitachi, Motorola, Alterra, Avago). Hence, the third industrial master plan (IMP3) appears more successful than IMP2 only because the government offered capital grants to foreign firms to stimulate functional upgrading. Hence, the components segment (mainly semiconductors) of the electronics industry has managed to grow again to overtake electrical-electronics equipment and parts as the leading sector in the industry since 2005 (see Figure 5).

Figure 5: Composition of the electrical-electronics industry in electronics value-added activities in per cent, Malaysia (1989-2013)



Source: Author's compilation based on data obtained from Malaysia, Department of Statistics.

While functional upgrading has since evolved, serious shortages in the supply of human capital, including quality graduates in the fields of science and technology in related electronics specializations, and the lack of frontier research on semiconductors has restricted firms' participation in R&D operations. As a corollary, science parks (for incubation) and research universities (for basic R&D) have not evolved adequately to support firms' participation in high technology activities. In addition, the government's largely facilitative regulatory without developmental role has restricted technological upgrading in the industry. Even the provision of grants by the government has not been accompanied by upgrading milestones. Existing initiatives by a handful of MNCs in such activities are largely propelled from their parent and subsidiary sites abroad.

8 Technological catch up

As discussed in Sections 3 and 4, the dynamic pillar of industrial policy constitutes the capacity to stimulate firms' upgrading from low to high value-added stages or in technological terms, firms' catch up to the technology frontier and eventually to leapfrog competitors. It was only in 1986, when through the Industrial Master Plan of 1986 that elements of technological upgrading and promotion of strategic industries were contained in the government's official policy framework (Malaysia 1986). However, because of the economic crisis of 1985-86, the implementation of upgrading policies only started following the introduction of the APITD in 1991. We focus on the semiconductor industry to undertake a profound assessment of technological upgrading in the most sophisticated pillar of the electronics industry.

Since industrial policy in Malaysia did not seek technological upgrading over the period 1971-86, markets were left to shape firm-level technologies. Nevertheless, intense competition in a technology creating industry, such as electronics, required that firms regardless of their location introduced best practices. Hence, especially in semiconductors, non-Japanese firms began introducing automation and just-in-time (JIT) practices from the late 1970s and mid-1980s respectively. The active use of learning and innovation strategies through kaizen practices that included small group activities, quality control circles, integrated materials resource planning, and statistical process control, proliferated into all semiconductor firms in Malaysia (Rasiah 2010).

Since the 1980s, the introduction of cutting-edge process control technologies increased incremental engineering practices especially in semiconductor firms (intensified since 1985), as cutthroat competition forced a shakeout in the industry. The rising demand for statistical and cognitive skills led to poaching as their supply became scarce in Malaysia following the relocation of the second major wave of electronics firms from Japan, Taiwan, South Korea, and Singapore since 1988. Most semiconductor firms had already moved to levels 3 and 4 in the technological capability ladder by the 1990s (Rasiah 2010). The floating of the currencies of these countries following the Plaza Accord of 1985 and the termination of the GSP from Taiwan, Korea, and Singapore in February 1988 triggered this relocation to most of Southeast Asia (Rasiah 1987). The collaborative initiatives that were launched to solve infrastructure problems, such as security, customs co-ordination, power and water supply, and transport and housing for workers, became a key channel to the founding of the Penang Skills Development Centre in 1989. The Penang state, the anchor in solving collective action problems, responded to firms' requests and offered a large building at a nominal cost for their use in order to stimulate training for the industry.

Firm-level horizontal technological upgrading can be classified as developments largely driven by firm strategies conditioned by competition with the government, especially the Penang government, playing a minimalist role as facilitator. Suppliers began to expand in the 1980s and early 1990s when the use of JIT practices and rapid technological obsolescence stimulated proximate sourcing (Rasiah 1994). Much of these upgrades arose from the absorption of best practices with automation and statistical skills acquisition dominating production operations of electronics firms, especially semiconductor firms.

Table 3 shows the extent of upgrading enjoyed by semiconductor firms by taxonomy and trajectory in 2014 from a sample of 25 semiconductor firms in Malaysia. The three lead firms in the semiconductor industry (i.e. Intel in microprocessors, Samsung in memory, and TSMC in logic chips); do not have their frontier operations in Malaysia. In 2014, seven foreign firms, enjoyed mature R&D competencies and capabilities.

It can be seen in Table 3 that none of the firms are at the frontier of all three embodied technological pillars (i.e. HR competencies and, process and product capabilities). Indeed, neither do any of the firms undertake frontier research in-house nor engage frontier research facilities in universities in Malaysia. All seven firms that reported having mature R&D competencies and capabilities are foreign owned (i.e. five American, one Japanese, and one German). All foreign and national firms enjoyed at least engineering-intensive operations. Whereas 20 of the 21 foreign firms were engaged in at least the early stages of R&D, only one of the four national firms reported undertaking such activities. Interviews showed that early stage supportive R&D in foreign firms had already started in the 1990s. However, their progression to substantial R&D activities only took place after the provision of grants, and the approval of permits to import foreign R&D personnel. The seven foreign firms with mature R&D capabilities reported that Malaysia lacked the requisite human capital, as well as, frontier research capabilities in the country to attract frontier R&D operations (level 7).

Table 3: Technological competency and capability, semiconductor firms, Malaysia, 2015

		HR		Process		Product	
Level	Type	National	Foreign	National	Foreign	National	Foreign
4	Engineering	4	21	4	21	4	21
5	Early R&D	1	20	1	20	1	20
6	Mature R&D	0	7	0	7	0	7
7	Frontier technology	0	0	0	0	0	0
	N	4	21	4	21	4	21

Source: Rasiah (2015).

The efforts of the provincial government of Penang to start the PSDC was instrumental in the federal government responding by launching a more institutionalized framework at the national level to support training through the enactment of the HR Development Act in 1992, which required that manufacturing firms with employment size of 50 or more contribute 2 per cent of their payroll to the HR Development Council. Firms can then claim from their contributions approved training expenses. The government had introduced a double deduction on taxable income scheme in 1988 that firms began to use, which has continued among firms with employment size below 50 employees. In addition, the government introduced grants following the launch of the APITD in 1991 but its implementation was restricted until 2005. Only Silterra and 1st Silicon, government-owned wafer fabrication firms that were spawned in 1995 but did not begin operations until 2000, were awarded grants until then.

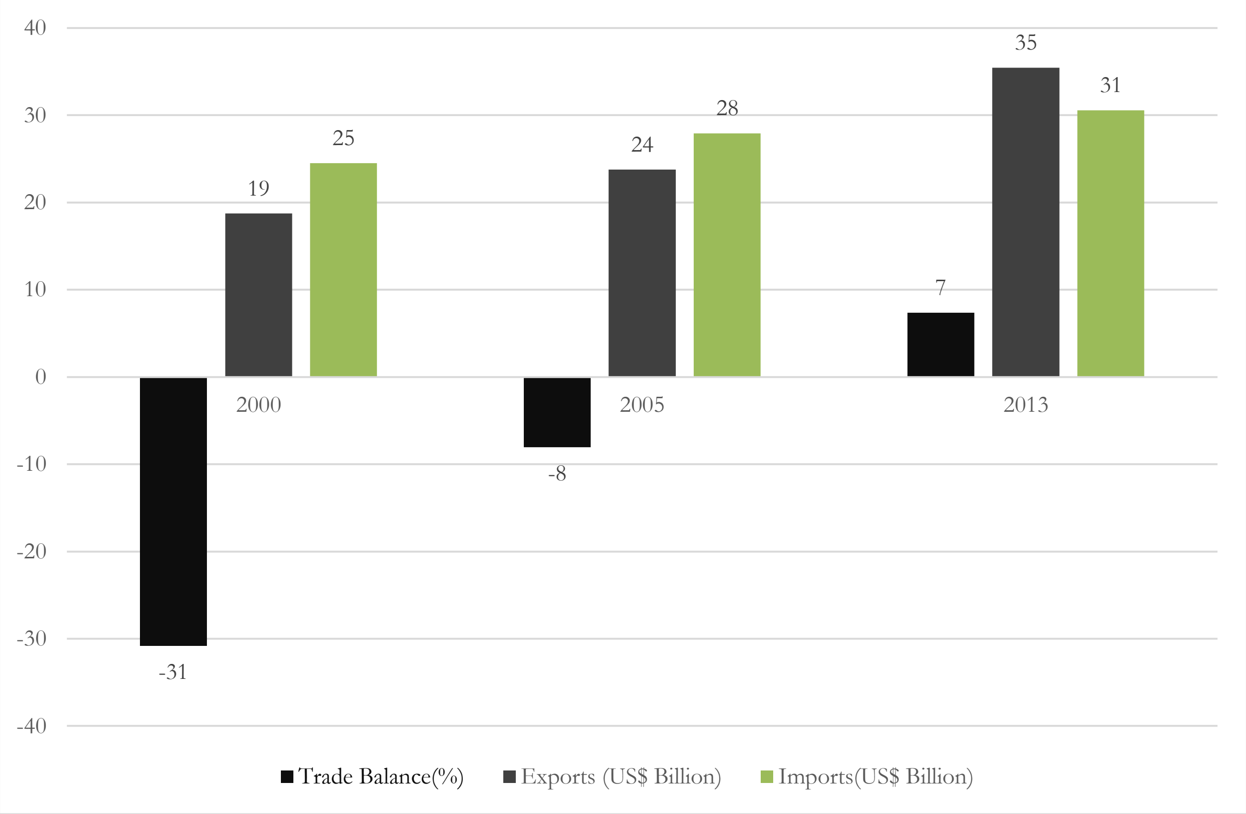
The government's efforts to launch the venture capital organization, Malaysian Technology Development Corporation (MTDC), and to corporatize MIMOS in 1993 did not yield significant results in the semiconductor industry. Arguably, the main effort of MIMOS has been the setting up of Silterra and 1st Silicon. The former is still far from the technology frontier, while the latter has been acquired by the foreign firm, X-Fab. Introduction of the Multimedia Super Corridor in 1995 offered broad-brand infrastructure to stimulate firms' participation in design but they have largely been confined to service activities.

While significant technological deepening has taken place among semiconductor firms, it did not attract much functional upgrading until 2005 with the integration of more knowledge-intensive stages, such as chip design, wafer fabrication, and chip implant activities. Semiconductor firms began to introduce the early aspects of R&D, with a focus on the development of machinery and equipment prototypes, modifications, and production and organizational restructuring in the 1990s. Firms that considered upgrading functionally, such as, Hewlett Packard and Intel, into wafer fabrication and chip design respectively in the late 1980s, did not do so because of lack of capital grants upfront from the government (Rasiah 1996). Hence, by confining government support to financial incentives (tax breaks), security, and basic infrastructure, the government managed to attract foreign semiconductor MNCs into Malaysia into labour-intensive activities. However, by not introducing the dynamic elements of industrial transformation, such as capital grants, to stimulate the introduction of chip design, wafer fabrication, and R&D, the industry enjoyed little functional upgrading until 2005. In addition, Malaysia lacked the human capital and related research universities to support firms' participation in the Schumpeterian 'gales of creative destruction' activities (Schumpeter 1943), such as the introduction of new generation technologies that can spur new cycles of innovation.

The risks associated with investing in massive fixed assets involving wafer fabrication and research-dominated R&D discouraged firms from extending functionally into these activities until 2005. Chip design is a complementary activity that thrives on the proximity of wafer fabrication, and hence, lack of the latter discouraged participation in the former. Nevertheless, software activities in chip design can be undertaken from locations far from wafer fabrication as is seen from such activities undertaken in Bangalore and Cyberabad, India, and in Haifa, Israel. The short supply of human capital in general and information technology (IT) specialists in particular has hampered the expansion of chip design in Malaysia.

Since 2000, Silterra and 1st Silicon enjoyed grants from the federal government to set up wafer fabrication in Malaysia, though both firms were engaged in old generation technologies. Nevertheless, the extension of R&D grants after 2005 attracted functional upgrading. Hence, the number of semiconductor firms that upgraded functionally into chip design and wafer fabrication production rose from none until 1999 to 11 in 2014. Broken down, there were four foreign firms in chip design, one national, and five foreign firms in wafer fabrication. Although no semiconductor firm in Malaysia is shaping the globe's technology frontier in product technology, expansion of the high value-added activities of wafer fabrication and chip design has helped turn the negative trade balance in the integrated industry to a positive one (see Figure 6). While chip design typically does not require grants, its expansion in Malaysia required grants (to train nationals) and approval of import IT engineers from abroad. Hence, the number of patents registered by semiconductor firms from Malaysia in the United States rose from seven patents over the period 1980-2005 to 309 patents in 2006-11 (Rasiah et al. 2015: 65).

Figure 6: Trade, electrical-electronics, Malaysia (2000-13)



Note: Trade balance estimated using the formula: (X-M)/(X+M) x 100 where X and M refer to exports and imports.

Source: Author's compilation based on WTO (2015).

While a number of semiconductor firms have ventured into functional upgrading since 2005, none has moved to participate in R&D activities associated with miniaturization and the enlargement of wafer diameter, which are the two key dimensions of frontier technology associated with semiconductor chips. In addition, none of the wafer fabrication plants in Malaysia are at the frontier. The flag bearers of such activity are Intel in microprocessors, Samsung in memory, and TSMC in logic chips. Despite the possibility of accessing R&D grants to undertake such activities, the short supply of engineers and R&D scientists, and the lack of frontier research at Malaysian universities were reported by two Chief Executive Officers of semiconductor firms to be the prime reasons for its absence in Malaysia (and Singapore). The lack of human capital endowed with tacit linkages with frontier R&D centres (including universities), buyer supplier firms, and the visionary experience to anticipate the next generation technologies (e.g., Maurice Chang of TSMC) has reduced meso-organizations, such as MTDC and MIMOS, and universities to truncated silos with little interaction with industry. The absence of such leadership restricted the capacity of national firms to enter and catch up technologically in the electronics industry like South Korea and Taiwan. The lack of frontier research centres—either at universities or at science parks—discouraged the development of frontier R&D and wafer fabrication activities in Malaysia. In addition, the lack of effective monitoring and appraisal restricted the capacity of the government to reduce the dissipation of rents offered through grants.

It can be seen that levels 5 and 6 technological activities have evolved in Malaysia, albeit in a handful of semiconductor firms. While the IMP2 provided some support for clustering activities, including the promotion of supplier networks, and recommended the provision of grants to promote R&D and wafer fabrication activities, there was little success. A combination of a lack of interest in providing foreign firms grants upfront restricted its provision to Silterra and 1st Silicon until 2005. Venture capital through government agencies, such as MTDC supported only a selected number of proven firms, such as Unico but generated little university linkages to electrical-electronics industry. The provision of grants upfront to foreign firms since 2005 has encouraged functional upgrading into chip design and wafer fabrication, and encouraged development in supportive R&D activities. However, these developments have not been subjected to strong governance to ensure technological catch up to frontier activities of R&D and wafer fabrication because of the lack of frontier research centres in semiconductor engineering (either at universities or public laboratories), and a critical mass of human capital. Hence, neither foreign nor national firms are engaged in level 7 HR competencies, process, and product capabilities in Malaysia.

9 Conclusions

Malaysia's electronics industry provides a mixed experience where the industry emerged largely with little intervention by the government other than the provision of financial incentives, security, and subsidized infrastructure at FTZs. The only developmental role the state played over the period 1971-90 was to approach actively foreign MNCs to relocate in Malaysia. Such liberal instruments managed to attract FDI inflows to generate employment and exports. Competition between firms and the specificity of the industry also saw significant horizontal technological development in the industry by the 1980s as firms introduced rapidly cutting edge process and production technologies Malaysia's small domestic market and the specificity of electronics specialization in semiconductors made export-orientation the only option to stimulate FDI inflows and rapid expansion. Import-substitution was never a workable option in this industry.

Nevertheless, liberal policies did not offer the institutional change required to spur significant functional upgrading vertically from low into higher value-added activities. There was a lack of high-technology organizations to solve collective action problems associated with public goods. Sensing such a shortcoming, the government introduced the APITD in 1991. However, while major meso-organizations; they failed to lead functional technological upgrading in the electrical-electronics industry. The provision of grants since 2005 has stimulated functional upgrading in the industry. However, the lack of research universities and laboratories undertaking frontier R&D in the electronics industry, and short supply of engineers and scientists were major weaknesses that have continued to discourage functional upgrades towards the technology frontier in the country.

Overall, the Malaysian experience with electronics in general and the semiconductor industry in particular shows that a minimalist role by the government that largely follows the direction of markets and, supplemented by good basic infrastructure and bureaucratic co-ordination when executed well can attract FDI inflows seeking low-wage labour. However, as labour reserves deplete it is not sufficient to sustain the technological upgrading required to support rising wages. Moreover, such policies are inadequate to stimulate technological development into R&D activities. While grants helped attract old-generation wafer fabrication into Malaysia, they were inadequate to attract cutting-edge R&D and wafer fabrication activities. Universities undertaking related research at the frontier, and a critical mass of related human capital are essential to attract frontier semiconductor manufacturing activities. There was a serious lack of focus on capability building in national firms in the technology transfer agreements like Japan, South Korea, and Taiwan. The political economy of ethnicity appears as a major constraint that has prevented the state from pursuing dynamic technological catch-up strategies in the country.

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