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Import substitution in high-tech industries:

Prebisch lives in Asia!

Alice H. Amsden

Prebisch "lives" in Asia because leading Asian governments still actively promote import substitution of high-tech parts and components. But they use promotional measures other than tariff protection to do so. Given performance standards, they have been highly successful. Now Latin America is behind Asian latecomers because it missed becoming a player in the information technology revolution. But Latin America can still learn from Asia rather than the Washington Consensus about how nationally owned enterprises can build mature high-tech industries in fields other than electronics.

Alice H. Amsden
Barton L. Weller Professor of Political Economy,
Massachusetts Institute of Technology (MIT)
amsden@mit.edu

I
Introduction

Raúl Prebisch became associated in the 1950s with Latin America's controversial policies of import substitution and anti-export growth.[1] Despite the rise of basic industry that resulted from that strategy, import substitution was disparaged for its inefficiency and balance-of-payments problems in the mid-1980s, if not earlier. The policies and institutions that had supported it were dismantled amidst a global wave of liberalization, and Latin America's markets were opened to exports from overseas and still greater investments from multinational firms.

Ironically, as Latin America was obliterating its past, Asia was reinventing import substitution for high-tech industries, and was growing faster than Latin America under a liberal regime. A high proportion of the value of many electronics devices (such as notebooks and cell phones) was initially imported. Government policy was oriented towards import substituting the parts and components that made up these products as a way to create high-paid domestic jobs and globally competitive nationally owned enterprises. The import substitution policies to promote high-tech production in China, India, Korea and Taiwan (hereafter referred to as Asia) were less distortionary than those used to promote mid-tech industry, insofar as they did not involve high tariff protection. Nevertheless, the Asian State began to play an extremely activist role in jump-starting the high-tech sector: a role with which Raúl Prebisch would have been familiar. In China, India, Korea and Taiwan, the governments were involved in the smallest details, such as cherry-picking specific companies for subsidies (in the form of residence in a science park, for example) and spinning off parts of government labs to create new firms.

Asia's promotion of science and technology and regional development deviated from the free market ethos of the Washington Consensus, but such interventionist measures were legal under the World Trade Organization (WTO). WTO members may still promote science and technology at the company level, much as the United States does through its Department of Defense (a staunch supporter of the computer industry) and its National Institute of Health (a champion of bio-tech). WTO members may also promote regional development (by offering subsidies to companies that locate in underdeveloped areas), as countries with North-South income inequalities tend to do in the European Union.

The first part of this paper is designed to convey the sheer extent of government intervention in high-tech industry, using Taiwan as an example.[2] This discussion should be of interest to economists who are considering how to develop the anaemic high-tech industries of Argentina, Brazil (somewhat less anaemic), Chile and Mexico.[3]

The last section of the paper speculates on why Latin America's high-tech industries have stalled and what would be necessary to get an Asian-type approach up and running. The emphasis is on national rather than foreign ownership.

□ This study was prepared originally for the seminar "Development theory at the threshold of the twenty-first century", organized by ECLAC in Santiago, Chile, to mark the centenary of the birth of Raúl Prebisch.

[1] The latter charge is unfair. As early as 1968, Prebisch strongly advised the Argentine government to combine import substitution with export activity (Mallon and Sourrouille, 1975).

[2] This section is based on Amsden and Chu (2003).

[3] Hereinafter, the term "Latin America" will be used to refer to these four countries.

II
National ownership and the high-tech industry

The emergence of high-tech industries in countries of relatively recent industrialization (“latecomers”) —even the mature high-tech industries that constitute most latecomers’ high-tech sector— requires entrepreneurship insofar as it entails the creation of the experienced human resources on which those industries depend. There is a great risk that such resources will exit from the firm that created them. Thus, either skill formation must initially be undertaken by the government, with the objective of diffusing capabilities to the private sector, or private firms must be entrepreneurial enough to grow and diversify sufficiently to retain the resources in which they invested.

As late as 2000, the high-tech sector in latecomer countries entailed mature products; Korea and Taiwan, for example, began to produce notebooks and cell phones only after such products had been produced in large volume in high-wage countries. Product maturity implies a relatively low gross margin that is rapidly falling over time. To reap profits in such an industry, a firm must enter quickly before profitability falls further, and it must produce at a high volume to overcome thin margins. Ramping up fast and adapting products in order to be quick to market involves risk-taking and entrepreneurship, since it requires investing in the creation of a new set of skills, coordinating their formation, raising the funds to finance this, and implementing and monitoring the whole process (Amsden and Chu, 2003).

The requisite skills may be cultivated by either State-owned or privately owned organizations, but nationally owned firms have a greater incentive than foreign-owned organizations to take the lead. National firms enjoy lower opportunity costs, more local knowledge and a higher probability of using the same sunk assets in a related local industry than do their foreign counterparts. The first entrants into a high-tech industry in latecomer countries are therefore likely to be nationally owned (State or private) entities. Multinational companies may once have played a formative role in developing labour-intensive, export-oriented industries in latecomers, and they may enter into high-tech industries and accelerate an existing growth momentum.[4] However, it may be assumed as a hypothesis that the pioneers of high-tech industry in latecomer countries will be nationally owned firms with either direct or indirect experience in mid-tech sectors or in another type of economic activity, such as marketing foreign products (Amsden and Hikino, 1994).

Table 1 shows the share of high-tech industry in manufacturing value added in selected Latin American and Asian economies for the years 1980 and 1995 (the last year for which comparable data are available). The higher share of high-tech in China, India, Korea and Taiwan compared with Argentina, Chile and Mexico is striking. Only Brazil compares with the Asian countries in the extent to which its manufacturing sector is dominated by high-tech.

[4] On the sequential timing of foreign direct investment, see Amsden (2001).

TABLE 1

Percentage of manufacturing value added in high-tech industries, 1980 and 1995

(Percentages)

1995	Argentina	Brazil	Chile	China	India	Indonesia	Korea	Malaysia	Mexico
Other chemical products	3.5	10.1	8.0	1.9	7.9	3.6	4.7	2.2	7.2
Non-electrical machinery	3.1	7.5	1.8	11.1	8.3	1.0	8.4	5.0	3.3
Electrical machinery	3.0	8.0	1.5	9.9	8.4	3.1	14.4	27.4	3.2
Transport equipment	7.4	10.4	2.0	6.3	8.5	8.9	10.7	4.7	10.1
Professional and scientific goods	0.4	0.8	0.2	1.1	0.7	0.1	0.8	1.2	1.7
Total	*17.4*	*36.8*	*13.3*	*30.2*	*33.7*	*16.6*	*39.1*	*40.5*	*25.6*
	Taiwan	Thailand	Turkey	**Rest (average)**		Japan	France	UK	US
Other chemical products	2.7	2.5	4.7	4.9		5.8	6.1	7.0	6.8
Non-electrical machinery	5.2	3.3	4.5	5.2		12.1	7.0	11.3	10.5
Electrical machinery	17.3	5.5	6.0	9.0		14.7	10.0	8.4	9.6
Transport equipment	7.4	5.2	6.7	7.4		10.6	10.9	10.4	11.6
Professional and scientific goods	1.0	0.9	0.3	0.8		1.3	1.5	1.6	5.8
Total	*33.6*	*17.3*	*22.3*	*27.2*		*44.4*	*35.6*	*38.8*	*44.3*
1980	Argentina	Brazil	Chile	China	India	Indonesia	Korea	Malaysia	Mexico
Other chemical products	4.9	4.9	6.5	3.3	8.1	7.1	5.2	3.2	5.2
Non-electrical machinery	5.5	10.0	1.9	15.1	8.6	1.6	3.4	3.2	4.8
Electrical machinery	3.7	6.3	1.8	3.6	8.1	5.3	8.1	12.3	4.4
Transport equipment	9.3	7.8	2.5	3.4	8.3	6.4	5.9	4.2	6.9
Professional and scientific goods	0.4	0.6	0.1	9.2	0.7	0.1	1.1	0.7	0.7
Total	*23.8*	*29.8*	*12.9*	*34.6*	*33.9*	*20.4*	*23.8*	*23.6*	*22.1*
	Taiwan	Thailand	Turkey	**Rest (average)**		Japan	France	UK	US
Other chemical products	1.0	2.7	3.6	4.7		4.6	3.9	4.6	4.6
Non-electrical machinery	1.9	1.9	4.7	5.2		11.6	10.1	13.0	13.3
Electrical machinery	7.0	3.8	4.3	5.7		11.5	8.9	9.3	9.7
Transport equipment	2.5	3.7	5.0	5.5		9.5	11.0	10.7	10.6
Professional and scientific goods	0.9	0.3	0.1	1.2		1.7	1.4	1.3	3.6
Total	*13.4*	*12.4*	*17.6*	*22.3*		*38.7*	*35.2*	*38.9*	*41.9*

Source: Amsden (2001).

These differences can be attributed to the ownership of the firms and to government initiative. In turn, the importance of national versus foreign ownership and the activism of the State have deep historical roots involving the nature of prewar manufacturing experience and technology transfer (Amsden, 2001).[5] Two major types of transfer may be distinguished: emigré and colonial. National ownership and government initiatives to promote high-tech sectors tend to be greater in countries with colonial —rather than emigré— prewar manufacturing experience.[6]

In the emigré form of experience, technological capabilities and business organizations were transferred by means of foreign individuals (and later companies) that located operations in a latecomer setting. Like the North Americans and Europeans in Latin America and the Chinese in Asia (Malaysia, Indonesia and Thailand), such emigrés are a major source of modern business know-how and skill formation. The boundaries between national ownership and foreign ownership become blurred, and government policy

[5] This paper does not discuss the cases of Malaysia, Indonesia and Thailand, whose manufacturing sectors are relatively young compared with the four Latin American and four Asian countries discussed. Malaysia's share of high-tech industry is high in terms of manufacturing value added owing to labour-intensive electronics assembly, which is not high-tech in terms of skill content. For a more detailed discussion, see Amsden (2001). Nevertheless, both Thailand and Malaysia have begun to invest heavily in R&D. Investments in technology in Indonesia were never negligible. Over 25 years ago, Indonesia sent a large contingent of engineers to the Department of Aeronautics and Astronautics at the Massachusetts Institute of Technology in order to build its aerospace industry.

[6] The measurement of national versus foreign ownership across countries in any particular industry, or in the manufacturing sector at large, is vexed by different definitions of "foreign" — the percentage of equity in an investment that is foreign owned. The available cross-country data, however, suggest that foreign direct investment (FDI) is much more important in the manufacturing industries of Latin America than in Asia (as defined above): see Amsden (2001).

towards promoting national ownership over foreign ownership is at best ambivalent. In identity politics, it is unclear who is a foreigner and who is a national.

In the colonial type of prewar manufacturing experience, business know-how and foreign skills were transferred by firms that resided in the home country of the colonial ruler. For example, the major nationality of foreign firms in India was British, while in Korea and Taiwan, it was Japanese. This form of technology transfer was favourable to national ownership because colonialism eventually ended in decolonization, which had many positive impacts on countries that had succeeded in acquiring prewar manufacturing experience. Foreign political rule was displaced by national political rule, and colonial firms typically were taken over by nationals. In Indonesia, roughly 400 Dutch-owned companies were left behind —albeit practically gutted— when Dutch domination ended (Lindblad, 1996). In India, British enterprise either sold out to Indian buyers or could not compete against them (Tomlinson, 1981). In Korea and Taiwan, Japanese manufacturing enterprise and banks fell into the hands of national governments (Amsden, 1989; Fields, 1995). In China, foreign-owned firms were appropriated after the Chinese Communist revolution. Decolonization thus cleared the way for nationally owned companies to grow, whereas emigrés tended to crowd out nationally owned firms in industries subject to economies of scale.[7] In turn, nationally owned firms, especially those originating in mid-tech industry, often became the entrepreneurs behind the rise of high-tech industries and services such as the computer industry, telecommunications, finance and high-speed trains, as in the cases of Korea and Taiwan.[8]

Decolonization also created a culture of nationalism, which gave rise to political demands for land reform and government policies to promote nationally owned firms and the high-tech industry. Economic nationalism took many forms, but all shared the objectives of creating an alternative to multinational enterprise and generating the wherewithal to move up the ladder of comparative advantage, beyond labor-intensive or raw-material-intensive industries. This required, first, government-owned national research and development (R&D) laboratories, such as the defence-related labs in China and India, which became breeding grounds for private high-tech industries, and second, investments in tertiary education, which tended to be high in Asia.

Finally, nationalism tended to foster an ethos of equality, which was patently absent under colonial rule. All four Asian countries discussed above introduced land reform in varying degrees of radicalism, with the most radical in China and the least in India. Land reform abolished the large estates that had earned Ricardian rents (that is, above normal profits) in prewar years. With such profit-making opportunities gone, the opportunity costs of investing in manufacturing industries were lowered, making manufacturing a more attractive financial venture than it had been when consolidated holdings of land and mining rights characterized the agricultural sector, broadly defined. The reduction of opportunity costs outside manufacturing also made it less costly for the government to subsidize manufacturing activity in order to lure capital and human resources out of agriculture and into new import-substitution manufacturing industries (Amsden, 2001).

The degree of high-tech activity, measured in table 1 as the share of high-tech industry in total manufacturing value added, therefore tends to be higher in Asia than in Latin America. The exception is Brazil, where the State launched a highly nationalistic project to develop local capabilities to manufacture mini-computers. This project was generally unsuccessful, in part because of weaknesses in tertiary education and lack of experience among nationally owned firms, which were stronger in the realm of finance than manufacturing (Evans, 1995; Sridharan, 1996).

The difference in high-tech development in Latin America and Asia can thus be attributed to history, specifically to whether prewar manufacturing experience was acquired through emigration or colonialism.

The question now becomes how and why to promote high-tech industry in emigré-dominated economies. But first the paper examines the case of Taiwan, where both the emigrés (from the Shanghai region of China) and decolonization were critical in moving beyond late development, based on mid-technology industries.

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[7] For the Argentine automobile industry, see Cochran and Reina (1962).

[8] On Taiwan, see Amsden and Chu (2003).

III
Government leadership in high-tech in Taiwan

The Taiwanese government's role in promoting high-tech was major insofar as it was meant to create the new market segments in which national companies could then compete. Its strategy featured import substitution and the germination of parts suppliers around a lead firm, or "second mover" (the first latecomer firm to enter a mature high-tech industry). Whereas the government had spawned new industries in the old economy using State-owned enterprises and import-substituting policy tools such as tariff protection, local content regulations and development banking, it did so in the new economy using spin-offs from State-owned research institutes and science parks, together with import-substituting policy tools such as subsidies to public and private R&D, tax breaks and financially favourable conditions for residents of science parks.

By 2000, there were more than 15,000 professionals in Taiwan who had at one time or another worked for ITRI, the government's premier research center devoted to high-tech industry.[9] Of these 15,000 professionals, more than 12,000 had, in fact, gone to work in such industry. Of these 12,000, 5,000 had been employed in Hsinchu Science-Based Industrial Park.[10] ITRI was also responsible for spinning off the two pillars of Taiwan's semiconductor industry, the United Microelectronics Corporation (UMC) and the Taiwan Semiconductor Manufacturing Company (TSMC).

The government sought to break technological bottlenecks to enable nationally owned second movers to compete globally in "new" high-tech subindustries, and then to pass on their know-how to local parts suppliers. By the 1970s, the fast growth of labour-intensive exports had depleted Taiwan's "unlimited" labour reserves, and major projects in heavy industry were already in place. It was thus strongly believed that the next set of growth opportunities had to be created in high-tech industry, and that the government had to play a major role in cultivating them. "To many policy makers in Taiwan, the classical price-mechanism type of resource allocation was simply too slow a process to promote industrial development. They advocated that more direct industrial policy measures be considered to speed up development of high-tech industry" (San, 1995, p. 35).

The government promoted high-tech industry on several fronts, including fiscal policy, the creation of science parks, and the pro-active investments of public R&D institutes, some of which assumed multiple roles. ITRI, for example, undertook key technology projects to give a head start to pivotal industries, such as semiconductors and personal computers (PCs). Its spin-offs thus became Taiwan's leading firms in integrated circuit design. ITRI also actively initiated projects to explore major areas in which it believed the private sector might profitably invest next. After an industry got started, ITRI would undertake smaller-scale projects to substitute for the importation of key components. The government's objective was always to create local growth opportunities and local value added, besides upgrading the level of local technology. All forms of promotion converged in industries judged to be strategic in terms of their technology intensity, value added, market potential, industrial linkages, energy consumption and pollution content.

The government passed the "Development of Critical Components and Products Act" in 1992 to select 66 inputs for import substitution in an effort to reduce a persistent trade deficit with Japan.[11] Despite a bias in favour of imports on the part of domestic users of high-tech components, scarcities of such components promised high prices and high profits for firms that could make them instead of importing them. Users of such inputs had an added incentive to make them in-house in order to stabilize their supply. For its

[9] ITRI is the Industrial Technology Research Institute.

[10] The ITRI (2001) and Industrial Technology Information Service (ITIS) reports are available at http://www.itri.org.tw/eng/about/annual/annual98/spec_pg3.jsp

[11] Taiwan's annual trade deficit with Japan grew in US dollars to about ten billion in 1991 from only two billion or three billion in the first half of the 1980s. Japan was the only trading partner against which Taiwan persistently ran a large trade deficit. Nevertheless, the share of Taiwan's imports from Japan out of total imports was relatively stable in this period; it remained at around 30%. Import dependence on Japan was thus probably a better indicator of Taiwan's technological dependence than its trade imbalance. Arguably, therefore, the passage of the "Development of Critical Components and Products Act" had less to do with trade structure than with industrial upgrading.

part, the government became committed to the substitution of imports of high-tech components to prevent hollowing out, or the movement of manufacturing jobs overseas.

Government leadership in strengthening science and technology (S&T) is illustrated below using the examples of compact disk-read-only memory devices (CD-ROMs), liquid crystal displays (LCDs) and integrated circuit (IC) design. Key government programmes are then briefly reviewed.

IV
Import substitution cum high-tech promotion

1. CD-ROMs

The CD-ROM, an optical storage device,[12] was chosen by the Taiwan government as a target industry in 1992 after extended discussion among government officials, academics and leading business people. Several related key technologies, such as the optical pick-up head, were also identified for promotion. The Department of Industrial Technology (DoIT) in the Ministry of Economic Affairs (MOEA) handled the so-called supply side: it invited research institutes, mainly ITRI, to submit R&D proposals to develop the selected items. Resources came from the Science and Technology R&D fund in four consecutive years, from 1993 to 1996. By the end of 1996, the total budget was roughly US$10 million.

The Industrial Development Board of the MOEA handled the so-called demand side by inviting private companies (based on specified criteria) to participate in the development process. The programmes involved were the “Regulations Governing the Development of New Industrial Products by Private Enterprises” and the “Regulations Governing Assistance in the Development of Leading Products.” These two programmes provided R&D grants to private enterprises to engage in new product development. The grants were to be repaid if and when sales actually materialized.

The CD-ROM project involved 25 firms in joint development and technology transfer.[13] Four patents were derived for CD-ROMs and 24 for CD-ROM pick-up heads. Ramp-up was astonishingly fast. As indicated in table 2, Taiwan’s share of CD-ROMs in world output rose from 1% in 1994 (218,000 units) to 50% only five years later (48,690,000 units).

TABLE 2
CD-ROM production, 1991-1999[a]

Year	Output, thousands of units		B/A	ITRI cooperation
	A. World	B. Taiwan	%	(number of firms)
1991	936			1
1992	1 050			7
1993	6 740			25
1994	17 966	218	1	25
1995	38 572	3 600	9	25
1996	51 000	9 170	18	25
1997	61 000	16 000	26	
1998	89 300	30 780	35	
1999	96 860	48 690	50	

Source: ITRI (1997) and Market Intelligence Center (various years).
[a] CD-ROM = compact disk read-only memory.

[12] Information on CD-ROMs is derived from the following sources: Industrial Development Bureau (various years), ITRI (1997), ERSO (1994), Hsiao (1994) and Market Intelligence Center (various, no. 2267).

[13] Interviewed firms include BTC, Inventec, Acer, U-Max, and Lite-On. BTC and Lite-On were also involved in the project to develop the CD-ROM pick-up head.

TABLE 3

Technological upgrading in the CD-ROM industry, 1994-1999

(Percentage of total output)

Year	CD-ROM read peed													Total
	2	4	6	8	10-12	16	20	24	32	36	40	44-48	>50	
1994	100													100
1995	40	47	13											100
1996			13	67	20									100
1997[a]						23	22	55						100
1998[b]								2	11	27	60			100
1999[b]										6	31	47	16	100

Source: Market Intelligence Center (various years).
[a] = second half; [b] = fourth quarter.

Although the firms that acquired CD-ROM technology from ITRI were able to begin assembly operations at once, and although the CD-ROM at the time was already a mature product, technological change continued to be rapid. As shown in table 3, manufacturers had to upgrade their know-how repeatedly to produce faster CD-ROMs. Moreover, they had to import key components from Japan. Local production of disks and spindles gradually came on line, but the two most critical inputs, the optical pick-up head and the ASIC set, were still being imported after 1996, although ITRI was in the process of developing them.

Taiwanese firms moved ahead of Japan as the major producers of CD-ROMs, but Japanese companies were shifting to other new and improved models, such as the DVD-ROM and the CD-RW. Most Taiwanese firms were reluctant to enter into DVD-ROM production because they considered the royalty fees demanded by Japanese companies prohibitive, but then ITRI transferred DVD-ROM technology to 13 firms in 1997. Around 2000 the price of the DVD-ROM was twice that of the CD-ROM, but replacement of one with the other was expected to be slow.

2. Liquid crystal displays (TFT-LCDs)

Liquid crystal displays[14] were pioneered in the late 1970s and 1980s by Japanese firms, first in their simpler forms (twisted nematic, or TN, and supertwisted nematic, or STN) and then in their more complex form (thin film transistor, or TFT).[15] The latter represented a great challenge to manufacturers owing to their extremely high financial and processing requirements. Profitability depended on low defect rates and high yields.

By the mid-1990s, some Korean chaebols (such as Samsung, Hyundai and LG), in collaboration with the ministries responsible for promoting technological innovation, had succeeded in entering the TFT-LCD industry and providing a modest challenge to Japanese hegemony. Some Taiwanese firms were competitively producing TN- and STN-LCDs by the early 1990s, but they hesitated to enter the more capital-intensive TFT-LCD market.

Two events probably pushed them into action. Prior to the 1997 Asian financial crisis, Samsung, Hyundai and LG had planned large expansions to catch up with Japanese manufacturers, but the crisis led them to mothball their plans. At the same time, Japanese business groups that were suffering from prolonged recession and overcapacity became unable or unwilling to continue making the huge investments in TFT-LCDs necessary to keep up with the competition. A few, therefore, decided to cooperate with Taiwanese firms by granting them technology licenses and giving them OEM orders.[16] Suddenly, therefore, leading Taiwanese firms announced plans to obtain technology from Japanese partners and make big investments to produce TFT-LCDs.

The entry of Taiwanese firms changed the global distribution of large TFT-LCD capacity. Taiwan's share of global capacity increased from zero percent in 1998, to 2% in 1999, 15% in 2000, and 26% in the first quarter of 2001. With these huge increases in capacity,

[14] Information on the liquid crystal display (LCD) industry is from Wong and Matthews (1998), Linden and others (1998) and ITRI (1999 and 2000b).

[15] An LCD is the best-known example of the type of microelectronic flat panel display which is used in electronic calculators, laptop computers and other applications.

[16] A joint venture between IBM and Toshiba formed in 1989 ceased making LCDs for computers in May 2001. Toshiba will use its Japan facility to make LCDs for cell phones, and IBM will use it for ultra-high-resolution applications such as medical devices (Nikkei Weekly, 2001).

the international price of TFT-LCDs fell sharply, and the price of a 14.1-inch TFT notebook panel dropped from US$1100 in the third quarter of 1997 to a little over US$600 in the fourth quarter of 2000. With large investments and falling prices, mergers and acquisitions came onto the agenda of the firms in this sector.

ITRI had initiated an R&D project on TFT-LCDs in 1988, but no Taiwanese firm relied on ITRI's technology when the time came to invest in TFT-LCD capacity. In this respect, ITRI's efforts were a failure. Nevertheless, the competitiveness of the high-tech groups that entered into TFT-LCD production in Taiwan depended on further technological development, and it was expected that ITRI would play a leading role at this higher stage. Indeed, it established Taiwan's first low-temperature polysilicone (LTPS) TFT-LCD laboratory in 2000 and has developed some key components for more advanced types of panel display.

3. Integrated circuit (IC) design

The basis of a networked semiconductor industry stemmed from the Taiwanese government's creation of two world-class semiconductor manufacturers: United Microelectronics Corporation (UMC) in 1980, which is still government-owned, and the larger Taiwan Semiconductor Manufacturing Company (TSMC) in 1987. Both were spin-offs from experimental IC factories set up by the government-owned Electronics Research and Service Organization (ERSO), although they emerged at different stages and from different projects[17] TSMC was also a "foundry" that specialized only in wafer production, eschewing investment in auxiliary operations, unlike the vertically integrated device manufacturers (IDMs) that dominated the semiconductor industry worldwide.[18] The specialization strategy was the outcome of a deliberate government decision influenced by a prominent State official, K.T. Li, and Morris Chang, who came to Taiwan at the government's invitation in 1985 to head ITRI and later TSMC.[19] Chang was a former senior vice president at Texas Instruments and had been the highest ranking Chinese-American in the United States high-tech industry.

Three IC design companies (Quasel, Mosel and Vitelic) were established in Taiwan with government support by returnees (Taiwanese living abroad who return to live and work in Taiwan) from the United States. In 1985, all three were in financial trouble, and they again requested government help.[20] They wanted a local specialized foundry that could provide them with much faster and better service than large-scale foreign integrated device manufacturers, who regarded their orders as peripheral to their main business. The intellectual property of a design was also better protected by a foundry than an IDM.

Taiwan's IC design industry leapt from eight houses in 1985 to fifty houses in 1988. Sales grew 175% in 1988 and 143% in 1989. This was "partly due to the growth of the domestic market and partly due to the establishment of TSMC".[21] In 1999, 91% of the fabrication work demanded by Taiwan's IC design houses was done locally. The top seven IC design houses are estimated to have accounted for 60% to 70% of total IC design revenue. In the same year, 62% of semiconductor output was sold locally.[22]

Taiwan's IC design companies benefited from local supporting industries other than foundries. The IC mask industry, like the foundry industry, was set up by the government. ERSO transferred mask technology from two American companies —IMR in 1977 and Electromask in 1980— and began providing commercial masking services to local IC producers. The responsible division was then spun off as the Taiwan Mask Corporation in 1989.[23] Having a domestic masking service is estimated to have saved local firms 20 days or more in the complete IC production cycle (Lin, 1987).

Some United States electronics firms had moved into southern Taiwan's export processing zone in the 1960s to do packaging, testing and assembly (such as

[17] ERSO is part of ITRI.

[18] The stages involved in the production of an integrated circuit are design, manufacturing, masking (or sealing), packaging and testing.

[19] UMC ultimately adopted TSMC's strategy and became less vertically integrated, assuming the structure of a foundry.

[20] ERSO started a multi-project chip programme with the National Science Council in 1983 to help build up IC design capabilities in Taiwan's universities (Chen and Sewell, 1996). Mosel and Vitelic merged in December 1991 and now manufacture and market worldwide dynamic random access memory (DRAM) chips and other products. Revenues were US$880 million in 2000. Quasel is no longer in business.

[21] Market Intelligence Center (1989, p. 390); see also Lin (1987) and Chiang and Tsai (2000).

[22] Ministry of Finance website (www.mof.gio.gov.tw/taiwan-website/5-gp/eu/tables.htm).

[23] See ERSO, 1994.

General Instrument, Motorola, Microchip and Texas Instruments). These industries were gradually localized; both Motorola and Microchip, for example, sold their packaging capacity to nationally owned firms in 1999. In that year Taiwan's packaging capacity ranked first in the world: 99% of domestic packaging demand was supplied locally, and local packagers got half their business from domestic firms (ITRI, 2000a).

The human resources involved in the IC design industry, like the IC industry as a whole, came largely from ERSO and other government institutions or programmes and, to a lesser extent, from abroad. Most of the early IC design houses, such as Syntek (1982), Holtek (1983), and PTD (1986) were either ERSO spin-offs or were set up by former ERSO staff. These firms, in turn, had unintended spin-offs of their own, such as Chip Design Technology (1985) and Tontek (1986), which spun off from Syntek. When foreign design firms, such as Motorola and Philips, set up IC design facilities in Taiwan in the late 1980s, they either recruited from ERSO or asked ERSO to conduct their training courses (Lin, 1987). Returnees became important only in the 1990s. Of the top ten IC design houses in Taiwan, it is estimated that two were run by returnees in 1989, but that number had increased to five by 1995 (Hsu, 1997).

V

Start-ups: firm-level targeting

Taiwan was one of the first latecomer countries in which venture capitalism flourished, playing a major role in supporting Taiwan's high-tech industry.[24] The government was the catalyst: it began promoting private venture capital funds to finance start-ups in 1983, and it also founded its own venture capital firm around the same time.[25]

Nevertheless, venture capitalism cannot be credited with Taiwan's large (although steeply declining) number of start-ups. According to venture capital data for 1995-2000, start-ups received only a minor share of funds. Of the five stages of a firm's life cycle (seeding, start-up, ramp-up, maturity and restructuring), start-up received only 13.3% of total venture capital funding in 1995.[26] Assuming the available data are accurate, the lion's share of funding went to ramp-up and maturity (the former included the transformation of privately held companies into publicly held companies through initial public offerings, or IPOs)[27] By 2000, the share of total venture capital allocated to start-ups had risen to 32.8%, but this was still below the share allotted to expansion and maturity.

In cases in which an outside agent incubated a start-up, that agent was typically the government rather than a private venture capitalist. The government sometimes nurtured a start-up directly, as in its founding of Taiwan's two world-class State-owned semiconductor foundries, UMC and TSMC. Usually, however, the government nurtured start-ups indirectly by providing them with the finance, facilities and access to bottleneck technologies that were necessary for them to grow.

A major form of incubation in Taiwan was the science park, with the first located south of Taipei in

[24] "Seventy percent of VC [venture capital] investments have been in computer-related and electronics sectors. The rest occurs in communications, industrial products, and medical/biotechnology. The concentration by Taiwan's VC on technological rather than traditional industries, which is similar to the case of Singapore and South Korea, can be explained by the tax incentives which channel VC towards technological enterprise investments" (Wang, 1995, p. 86).

[25] In 1983 the Ministry of Finance introduced a statute ("Regulations Governing Venture Capital Investment Enterprises") that laid down guidelines for the organization of venture capital firms, their minimum capital requirements, and rules for the management and supervision of their funds. The first venture capital company to be created was Multiventure Capital Corp. (1984), a joint venture between Acer and Continental Construction. A second joint venture was founded in 1986 between an American venture capital firm (Hambrest & Quest) and various government agencies, in which 49% of the firms' minimum capital requirements came from the government's development fund (the Executive Yuan) and a quasi-development bank (Chiao-Tung). See Tzeng (1991) and Taiwan Venture Capital Association (www.tvca.org.tw/indexe.htm).

[26] The funding of start-ups by the venture capital industry may have been more important in the 1980s than in the 1990s. It has been estimated that of the 80 firms operating in Hsinchu Science Park in 1987, as many as 43 were financed by venture capitalists (Liu and others, 1989).

[27] "The achievements of VCs in directing technological enterprises about how to go public with their stock are considerable" (Wang, 1995, p. 90). Public offerings were the major exit strategy of venture capital investors.

Hsinchu and the second in Tainan in southern Taiwan. Start-ups were cherry-picked by the government for residence in these parks. Park residents received a set of comprehensive and generous subsidies that included tax and import duty exemptions, grants and subsidized credit, below-market rents for high-quality factory buildings or sites, living amenities for high-calibre researchers (including bilingual language instruction for expatriates' children), and access to government and university research facilities. "The engine of economic growth in the 1980s in Taiwan [was] the information industry, while the science-based industrial park [was] the driver of that engine" (Liu and others, 1989, p. 35).[28] Hsinchu Science-Based Industrial Park accounted for a large and increasing share of Taiwan's total R&D spending —as much as 18% in 1998— although it accounted for less than 1% of total output (sales as a share of gross national product). Finally, while the number of Ph.D.s in Taiwan grew from 6,000 in 1990 to roughly 16,000 in 1998, the share employed by firms in Hsinchu Science-Based Industrial Park rose just as sharply, from 2% to over 6% in the same period.

VI
Performance standards

Thus, despite the government's lip-service to liberalization and despite its opening of markets to greater foreign competition, industrial policy continued to play an important role in Taiwan's high-tech industries. The general success of industrial policy (as measured by global market share in information technology) stemmed from the maturity of the technology Taiwan was acquiring and to the performance standards observed.

The high-tech products that Taiwan targeted for import substitution were already mature by world standards, in that sales had already reached a high level before the products were manufactured in Taiwan. Thus, the government's targeting was not a shot in the dark: national enterprises had to face economic uncertainty, but they were not also confronting the technological unknown. Still, the potential margin of error on the government's part was large because technological uncertainty was not necessarily trivial even among mature products. For example, the government made the right choice, among several possibilities, in the case of information technology. Its "decision to bet on CMOS proved critical for Taiwan's ability to synchronize the development of semiconductor technology and its PC-based information technology so as to achieve a high synergy effect" (Chang and Tsai, 2000, p. 187)[29] The government's choices were based on careful and concerted studies of technological developments and trends by committees of government, business and university experts. In addition, the allocation of subsidies generally succeeded because, as in the past, the government tied the support to concrete, measurable and monitorable performance standards.[30] What was different in the high-tech stage of upgrading was that these standards tended to emphasize investment in assets that were knowledge-based.

Performance standards functioned in Taiwan's high-tech industries on two dimensions: as criteria that firms had to meet to be eligible for government subsidies, and as a condition for continuing to receive the incentives granted. The government had to be selective because the demand for subsidies by firms and research institutes exceeded supply. Conditionality itself worked because Taiwan's manufacturing sector —as evidenced by interviews with firms— had accumulated enough experience and skills to potentially produce high-tech products profitably. As projects became profitable, they generated the revenue for beneficiaries to repay their loans and to meet government R&D requirements — the programme's cardinal condition. Successful projects, in turn, reinforced the government's commitment to promotion.

[28] See also Chang (1992), Yang (1998) and Hsinchu Science-Based Industrial Park (2000), publication no. 2309.

[29] CMOS stands for complementary metal-oxide semiconductor. For more about this decision, see Chang and others (1994).

[30] For a general discussion of performance standards in the success of government intervention in late industrialization, see Amsden (2001).

The conditions for admission into Hsinchu Science-Based Industrial Park (*circa* 1980) were as follows:

i) A firm had to have the ability to design products for manufacturing according to a business plan;
ii) It had to have produced products that had undergone initial R&D that was still in process;
iii) It had to have manufactured products with a potential for development and innovation;
iv) It had to have experience in high-level innovation and R&D in a research department that conformed with a minimum specified size;
v) It had to have adopted production processes that required either training in advanced technology or the spending of fairly large sums on R&D;
vi) It was required, within three years after marketing a product or service, to employ a staff with no less than 50 % local technical personnel; and
vii) Its operations had to contribute significantly to Taiwan's economic reconstruction and national defence (Liu and others, 1989).

Winners were selected by a tripartite committee of experts drawn from private industry, government and academic circles, as in other government programmes.

To qualify for government funds for strategic products or industries (such as CD-ROMs or TFT-LCDs), the following standards had to be met:

i) Firms had to demonstrate their financial soundness and economic capabilities;
ii) They had to prove that they operated a research department; and
iii) They had to demonstrate substantial past R&D achievements.

Once a product receiving government promotion was successfully developed, intellectual property rights were handled as follows:

i) Ownership was shared equally, as jointly owned property, by the Ministry of Economic Affairs (MOEA) and the firm that had developed the product, since the government had invested 50 % of total development costs;
ii) If the MOEA wished to sell part of its intellectual property rights, the firm that shared these rights with the government had the right of first refusal; and
iii) In the event that the firm failed to engage in production or to initiate sales of the targeted leading product within three years after the completion of the development plan (for reasons such as bankruptcy, marketing strategy or operational difficulties), the firm not only lost its intellectual property rights entirely, but also had to repay in installments the money the government had invested.

To receive subsidies for R&D, firms in strategic industries had to commit to spending a certain fraction of their own revenues on additional R&D. The fraction partially depended on firm size: the larger the firm, the greater the fraction. If the amount spent was below the prescribed ratio, then the firm had to contribute the balance to a research and development fund designated by the government.

All told, the government pro-actively promoted the accumulation of knowledge-based assets in strategic industries to maintain Taiwan's standing as a production base. The performance standards it exacted for its subsidies further promoted high value added.

VII
High-tech industry in Latin America

A high-tech industry is one whose technology is still tacit rather than explicit owing to firm-specific, proprietary capabilities that create novel products and earn above-normal rents. High-tech industries are thus desirable for a country because they require high-wage, skilled workers and offer opportunities for entrepreneurs to earn technological profits. By definition, the rate of return of a high-tech product is still above normal for a latecomer even when technology is mature by advanced-country standards.

The domination of the United States and Asia in electronics makes it very difficult for newcomers to enter this field. In the case of Asia, not only is the region the low-cost manufacturer of virtually all mature electronics products owing to well-developed private firms and national innovation systems, but Asian producers also benefit from national and regional external economies (Fujita and others, 2000).

Latin America has two possibilities to create high-tech industry and, concomitantly, the firms and skilled workers necessary for such industry to thrive. First, it can "induce" foreign-owned firms that dominate industries such as automobiles to do more R&D locally. As evident from table 1, a broad definition of high-tech includes industries that are not especially R&D-intensive, such as transportation equipment, alongside electronics and chemicals, for example, which are the two most R&D-intensive industries. Nevertheless, leading producers of automobiles, such as Volkswagen and General Motors, have large corporate laboratories at home. They have an incentive to transfer R&D activity to latecomers owing to lower engineering costs. They also have a disincentive to do so, however, given the shortage of experienced skilled workers, uncertain property rights, and an unwillingness on the part of scientists at corporate labs to relinquish control over the most interesting research projects. Top management wants to keep these projects at home, under surveillance.

The Singapore government was able to overcome these resistances on the part of foreign firms, which accounted for about 80% of the country's total manufacturing value added, by systematically and deliberately creating a system of incentives and a set of institutions to make foreign firms do more local R&D (Amsden and others, 2001). In fact, the most advanced and promising R&D in terms of skill formation and new product development was undertaken by government-owned labs, acting independently. Such labs also worked with foreign companies to help them solve their production problems and, later, problems related to more advanced research. In addition, the government was scrupulous in protecting intellectual property and in subsidizing research and training by the private sector. This contributed to an increasing effort on the part of foreign firms to undertake R&D in Singapore. A similar scenario could be imagined for Latin America.

Second, Latin America has excelled in the production of petrochemicals. Some countries, especially Brazil and at one time Argentina, were also good at pharmaceuticals. These two industries, combined with bio-tech, comprise a large sector with diverse opportunities for new, high-tech products.

TABLE 4

Research and development expenditure , 1985 & 1995

(As a percentage of gross national product)

	1985[a]	1995[b]
Korea	1.8	2.8
Taiwan	1.2	1.8
India	0.9	0.8
Chile	0.5	0.7
Brazil	0.7	0.6
Turkey	0.6	0.6
China	...	0.5
Argentina	0.4	0.4
Malaysia	...	0.4
Indonesia	0.3	0.1
Thailand	0.3	0.1
Mexico	0.2	0.0

Source: All countries except Taiwan: UNESCO, various years; Taiwan: Taiwan National Science Council, 1996.

[a] The data are for the following years: India and Indonesia, 1986; Brazil, Korea, Mexico and Turkey, 1987; Chile and Taiwan, 1988.

[b] The data are for the following years: Malaysia, 1992; Mexico, 1993; India and Korea, 1994.

Whatever the potential, R&D for all industries to date accounts for a much lower share of gross national product (GNP) in Latin America than in Asia (table 4). Very few Latin American firms are active in R&D, including firms in Brazil (Alcorta and Peres, 1998). The education system is not oriented towards research that has industrial applications, and government laboratories have been neglected in the liberal spirit of cutting back public expenditures. Latin America must therefore undertake substantial policy making and institution building if it is to promote high-tech industry. The problem is not the rules of the WTO (although these generally don't help), but rather the inappropriate technology-related institutions that exist as a result of the Washington Consensus.

Institution building in favour of high-tech growth was a major part of Taiwan's success, as seen above in the case of the CD-ROM, TFT-LCD and IC design industries. These institutions, which involved a large but disciplined role for the government, were of the type that motivated Raúl Prebisch's writings on economic development. Hence, it is true to say that Raúl Prebisch lives in Asia.

Clearly, most investments in new technology, whether private or public, fail. If countries do not invest in technology, however, their economies will almost certainly fail too. Will Latin America open the door again to neo-Prebisch policies, this time aimed at building industries that are high tech?

(Original: English)

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