Internationalisation of Innovative Capabilities: Counter-evidence from the Electronics Industry in Malaysia and Brazil[1]

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ABSTRACT

The focus of this paper is to examine the extent to which firms in the electronics industry in Malaysia and Brazil (Manaus) have developed significant levels of innovative technological capabilities. By examining whether innovative capabilities have spread to these two late-industrialising countries, the paper seeks to add new evidence to the debate of internationalisation of innovative capabilities and to argue against existing generalisations. Internationalisation of innovative capabilities is measured here by the technological capability types and levels that have been built within firms. The framework for capability building identifies types and levels of technological capabilities. The paper draws on empirical evidence from 82 electronics firms – TNC subsidiaries and local firms: 53 in Malaysia (Penang and Klang Valley) and 29 in Manaus (Northern Brazil). Empirical evidence has been collected during extensive fieldwork based on different data-gathering strategies. the study has found that the capabilities of most of the sampled firms in Malaysia and Manaus have been upgraded to carry out diverse types of innovative technological activities. Additionally, these capability-building efforts are strongly associated with higher capabilities for local decision-making and control, automation level, and efforts to increase exports. Indeed, the study has found pockets of innovative firms that innovate to be competitive by reducing costs, being more productive, reducing lead time and producing better products – regardless of whether they are in an import-substitution country or in an export-oriented country.

1. Introduction

The debate related to the internationalisation of firms' innovative capabilities involves two main perspectives. The one that claims that internationalisation of capabilities hardly occurs (e.g. Vernon, 1966; Pavitt and Patel, 1991; Patel, 1995; Daniels, 1997). The other claims that internationalisation occurs depending on the location and situation of the host and home countries of trans-nationals corporations (TNCs) and product types (e.g. Mansfield et al., 1979; Cantwell, 1995, 1999; Mansfield and Romeo, 1984; Dunning, 1994a,b; Zander, 1994, 1997; Granstand et al. 1993). However, both perspectives have been based primarily on patenting, research and development (R&D) statistics and macroeconomic data. Additionally, analysis related to internationalisation of innovative capabilities is focused exclusively on TNCs and the world's largest firms and their affiliates in advanced industrialised countries (e.g. Patel, 1995; Pavitt and Patel, 1991; Mansfield et al., 1979; Dunning, 1994a,b; Cantwell, 1995; Zander, 1994, 1997; Patel and Vega, 1999). They largely ignore the process of internationalisation in local latecomer firms and TNC subsidiaries operating in late-industrialising countries. Even when TNC subsidiaries operating in these countries are included in the analysis, they would be classified as having hardly any internationalisation of

[1] This paper derives from extensive fieldwork conducted in Malaysia, through SPRU – Science and Technology Policy Research, University of Sussex, UK, and in Brazil (Manaus), through the Research Programme on Technological Learning and Industrial Innovation at the Brazilian School of Public and Business Administration, Getulio Vargas Foundation (EBAPE/FGV) and the Institute of Management and Economics (ISAE/FGV), Manaus, AM.

innovative capability (e.g. Ghoshal and Barnett, 1987). However, as most firms in late-industrialising countries start up without basic innovative capability to carry out innovative activities, it would be more useful to take into account the starting point of firms and examine the extent to which they move from basic to more advanced levels of capability development. Consequently, while most existing studies are relevant to the context of *industrialised countries* – where innovative capabilities have already been substantially created in industry – they have less relevance in the context of *industrialising countries*, like Malaysia and Brazil. In these countries, as a major component of the process of late industrialisation, significant innovative capabilities in industry still have to be built up. Thus, these questions have not been thoroughly and systematically addressed. Additionally, since many of the old theories, probably like Vernon (1966), and uninformed opinions do not address these questions, there are gaps left open for the continuing acceptance of certain arguments.[2] As a result, old ideas may be used for industrial policy. Additionally, perhaps because of the absence of studies that focus on the building of innovative technological capabilities in TNC subsidiaries and local firms in the electronics industry, common generalisations have been disseminated about technological development in Malaysia and Brazil (Manaus).[3]

One of the main generalisations about Malaysia is that TNC parents control core technologies and higher value-added production stages, while their subsidiaries are involved only in labour intensive operations for final assembly and build up little or no innovative capability, as reflected in several studies (e.g. MIER and DRI/McGraw-Hill, 1996; Ali, 1992; Guyton's, 1994; Danaraj and Chan, 1993; Yamashita, 1991). On the other hand, a slightly different picture has been suggested by some studies in the last four years. For example, that TNC subsidiaries had significantly increased their levels of automation from the late-1980s and that productivity had increased considerably (Ali and Wong, 1993). Similarly, a UNDP study found high level of technology in the production processes in electronics subsidiaries in Penang, particularly in US subsidiaries in the semiconductor sub-sector (UNDP, 1994). However, these studies have not focused on the development of technological capabilities. Among the generalisations relative to Manaus (Northern Brazil), over the past 25 years there has been an absence of studies of technological capability development in that area. The existing studies (if any) focus on macroeconomic issues rather than on technological development. For instance, even today the arguments and views about technological development in Manaus have not changed in relation to studies from the mid-1980s. At that time, it was argued that 'companies continued doing simple assembly manufacturing, characterised by a high degree of technological dependence' (Baptista, 1988: 313-4).

Additionally, foreign subsidiaries and local firms in Manaus are thought to have little or no independent innovative capabilities. For instance, there is a widely held view that the electronics industry in Manaus, is a set of 'screw-driver' plants or 'warehouses' doing simple assembly only to take advantage of tax benefits (see, for instance, Forbes Brasil, 25/10/2000: 64). Nevertheless, among the scarce studies on the Manaus electronics industry that emerged during the 1990s, Frischtak et al. (1994) provide a more positive view by suggesting the existence of updated manufacturing capabilities. However, this fact was only briefly

[2] As far as Vernon's ideas are concerned, we recognised that in a paper published in the 1970s (see Vernon, 1979), he discussed the development of innovative capabilities in countries other than the USA. More important, in his 1966 paper he even predicted (against the prevailing orthodoxy) the development of mass production in low-wage countries.

[3] For more details about these common generalisations relative to technological development in the electronics industry in Malaysia and Manaus (Brazil) see, respectively, Ariffin and Bell (1999) and Ariffin and Figueiredo (2001).

commented on the basis of, apparently, a small number of visits to some firms. Additionally, Frischtak et al. (1994) did not go further to examine, in the light of proper analytical frameworks, the types and levels of technological capabilities built in that industry in Manaus. The focus of this paper is to examine the extent to which firms in the electronics industry in Malaysia and Brazil (Manaus) have developed significant levels of innovative technological capabilities. In other words, by examining whether innovative capabilities have spread to those two late-industrialising locations, the paper seeks to add new evidence to the debate of internationalisation of innovative capabilities and to argue against existing generalisations. We recognise that a more comprehensive analysis of the issue of internationalisation of innovative capabilities should take into account an analysis of the learning mechanisms and inter-organisational links and knowledge flows underlying the technological capability development. However, this issue is outside the focus of this paper. Nevertheless, in the original studies underpinning this paper, the role of the inter-firm learning mechanisms in influencing the capability development in firms of the electronics industry in Malaysia and Manaus has been examined in detail (see Ariffin, 2000; Ariffin and Figueiredo, 2001). Section 2 introduces a framework to examine technological capability development, in the context of the electronics firms in Malaysia and Manaus. The research design and methods are outlined in Section 3 and the empirical evidence related to technological capability building in the sampled firms is examined in Section 4. Finally, Section 5 outlines the conclusions and some implications for policy.

2. A framework for technological capability building

This paper adopts a framework developed in Lall (1992) and later adapted in Bell and Pavitt (1995), because it uses a relatively fine disaggregation of different levels and types of technological capability.[4] Following Lall (1992) and Bell and Pavitt (1995), the framework indicated in Table 1 distinguishes between 'routine' production capability and 'innovative' technological capability.[5] 'Routine' production capability is the capability to produce goods at given levels of efficiency and given input requirements; it may be described as technology-using skills, knowledge and organisational arrangements. 'Innovative' technological capability is defined as the capability to create, change or improve products, processes and production organisation, or equipment. It may be described as change-generating capability, consisting of technology-changing skills, knowledge, experiences and organisational arrangements. Innovative technological capability is further disaggregated into different levels or 'depths' – from fairly 'basic' levels (e.g. from minor adaptation and incremental quality improvement) through 'intermediate' levels (e.g. for various types of product and process design and engineering) to more 'advanced' and 'research-based' levels (e.g. for developing the knowledge base for new product and process designs), with only the latter likely to involve the kind of activities usually described as 'R&D". Even though research-based levels,

[4] There are other ways of assessing firms' technological capabilities, for example, R&D expenditure (Mansfield, 1979), individuals' qualifications (Pack, 1987; Jacobsson and Oskarsson, 1995), investments in R&D personnel (Wortman, 1990), and patenting (Patel and Pavitt, 1997). However, most of these indicators, particularly those based on individuals' skills, do not take into account the organisational setting where technological capability is developed and the technological characteristics of latecomer firms.
[5] The methodological procedures to adapt this framework for the electronics industry are described in Ariffin (2000). Earlier adaptation and application of the original framework is found in Figueiredo (2001).

Table 1. A Framework for Technological Capabilities in the Electronics Industry

Types Of Capability Levels of Capability	Project Management	Equipment Tool & die, metal stamping, plastic moulding	Process and Production Organisation	Product- centred
ROUTINE PRODUCTION CAPABILITIES: CAPABILITIES TO USE AND OPERATE EXISTING TECHNOLOGY				
BASIC OPERATION Level 1	Engaging prime consultant. Preparation of initial project outline. Construction of basic civil works. Simple plant erection purchase equipment.	Basic maintenance but equipment suppliers stationed at plant.	SKD (semi-knocked down): parts assembly, only final assembly. Assemble kits: dissamble and re-assemble kits. PPC: production planning and control. Organising basic process flow. Visual testing only.	Routine QC to maintain basic standards: in-coming, final product inspection, out-going inspection.
BASIC OPERATION Level 2	Installation, maintenance, servicing, Simple customising of existing systems. Basic plant erection	Routine maintenance of tools and equipment. Total Preventative Maintenance (TPM). Total Productive Maintenance. Replication of unchanging items of equipment.	Process flow, line balancing. Assemble separate parts into complete assembly CKD (complete knocked down): complete assembly: PCBA and product assembly. Efficiency improvement from experience in existing tasks. Routine testing.	Replication of fixed specification Routine QC to maintain existing standards: in-line QC Minor clean-up of design to suit production or market.
INNOVATIVE TECHNOLOGICAL CAPABILITIES: CAPABILITIES TO GENERATE AND MANAGE TECHNICAL CHANGE				
BASIC INN0VATIVE CAPABILITY Level 3	Systems integration. Provide project management services to customers. Providing customised software solutions	Repair & trouble-shoot equip problems. Copying and simple adaptation of existing designs and/or specifications. Set-up Equipment Design, Tool, Die & Mould Development centres. Engineering/fairly precision metal and plastic parts.	Set-up of Process, Production or Industrial Engineering Dept/s. Improved layout & debugging to optimise production. ISO9002, SPC, QCC, TQM, Do in-circuit testing, burn-in. MRP or JIT systems.	Set-up of Product Engineering, Product Design dept/s. Product design for manufacture (DFM), Cost-effective, incremental product development for local or different markets. Cosmetic and mechanical design.
INTER-MEDIATE INN0VATIVE CAPABILITY Level 4	Software development. Project management of large-scale investment projects, international investments.	Develop automated equipment. Equipment Design Centre upgraded to separate firm. Mould & die design. High precision tooling, progressive metal stamping, plastic injection moulding.	Automation of processes, Flexible & multi-skilled production. Business process re-engineering. Dev new process specifications. Able to transfer to production directly from R&D design or drawing by HQ.	Design Centre upgraded to separate firm. Own product design for local or regional markets. Electrical, PCB, Chassis, Chip-on-board, Platform designs. Design for testability and debug-DFT/DFD ISO9001, Software development, systems engineering.

ADVANCED INN0VATIVE CAPABILITY Level 5	Projects management on a global scale. Full turnkey solution. Recognised training & service centres to TNC Group, customers or suppliers.	R&D for specifications and designs of new high precision tools, complex automated equipment or production systems. Patents.Set-up of recognised training institutes in precision tool & die, or precision plastic moulding with universities.	Radical innovation in organisation. Own-developed CIM with customers, vendors or Group. In-depth Failure Analysis. Developing manufacturing, FA and TestCAD software tools, Patents.	Rapid prototyping, VLSI design. Package electrical design.Substrate and piece parts design. Materials and surface analysis. Upgraded to regional or worldwide Design Centres or world product mandates. Providing design services to TNC Group or customers.
RESEARCH-BASED INNOV CAPABILITY Level 6		Fast time-to-design cutting-edge and hi-prec equipment to produce latest or cutting-edge products and components Is among regional or global leader of CNC complex equipment, high precision tooling, stamping, die & mould, prototype models.	Process and software development to produce & test high yield, miniaturised and higher performance HDD products and chips. Time-to-volume production. Research into advanced material and new specifications to produce future or cutting-edge products.	Is a leading regional or international R&D, product development, ASICs or software design centre/s. R&D into new product generations using leading-edge technology, larger wafers, higher performance HDD & chips.

Source: Ariffin (2000)

which involve activities at the tip of the iceberg, may be less applicable to firms in a production-based electronics industry in a late industrialising country, it provides a perspective and link to total technological activity in the global electronics industry. This framework, thus, provides a basis for describing one of the two trajectories of technological development: progress from routine production capability to successively higher levels of creative and innovative technological capability. This trajectory should be distinguished from the other involving progress through increasingly complex and higher value products. That is, a firm's progression in technological activities (e.g. from minor product modifications in the mid-1980s to core design of its products in the late-1990s) should be distinguished from types of products or components it produces – for example, from simple analogue radios in the 1970s to the latest audio products in the late-1990s. [6]

3. Research design methods

This paper has been designed to address the following question and null hypothesis:
Has internationalisation of innovative technological capabilities spread to firms in the electronics industry in late-industrialisation locations like Malaysia and Manaus?
Null hypothesis: Foreign TNC subsidiaries and local firms as a whole have not built significant technological capabilities, and thus, the internationalisation of innovative capabilities has not spread to a developing country like Malaysia and a developing area like Manaus (Brazil).

3.1 Empirical setting and sampling

This paper draws on data from a sample of 53 electronics firms in Malaysia (25 in Penang and 28 in Klang Valley) and 29 in Brazil (Manaus). Penang is located in Northern Malaysia,

[6] There are other frameworks for technological capability in latecomer firms: the 'reversed product-cycle' (Hobday, 1995) and the 'acquisition-assimilation-improvement sequence' (Kim, 1997). However, these frameworks, despite their merits, are more focused on product capabilities: they do not cover other technological activities like process and production organisation, equipment and project engineering.

while the Klang Valley covers the central region of Selangor and Kuala Lumpur. These two areas have the highest concentration of employment and are the oldest in the electronics industry in Malaysia. Manaus, the capital city of the Amazonas state, in Northern Brazil, concentrates the majority of consumer electronics manufacturing plants in Brazil. These locations have been studied because they have some common characteristics: (i) they started at about the same time in the late-1960s to early-1970s; (ii) they are free trade zones; (iii) they are leading electronics industry clusters in their countries; and (iv) they started only as low-cost assembly operations. However, while in Malaysia the electronics industry focused on an export-oriented industrial strategy, in Manaus it focused entirely on the domestic market, particularly until the mid-1990s. This is what is interesting to compare in terms of possible differences in innovative capability of firms in Malaysia and Manaus. The key criteria to select the firms were based on purposeful sampling. As opposed to probability sampling, the logic and power of *purposeful sampling* is to select information-rich cases from which one can learn a great deal about issues of central importance to the purpose of the research (Patton, 1990; Yin, 1994). Following Hobday (1996), the research classifies firms in Malaysia and Manaus electronics industry in three groups: Group 1: *TNC subsidiaries* of US, Japan, European and Taiwan origin or ownership; Group 2: *local firms* – suppliers in the supporting electronics sector that are mainly dependent on sales for Group 1; and Group 3: *local independent firms* – local firms that sell their products to a more general market, either domestic or export market, and are fairly independent of specific TNC subsidiaries in Malaysia and Brazil for sales. Unlike Hobday, this group consists of both large and smaller firms (see sample composition in Table 2). Firms from the Malaysia sample represent 53% of the 100 identified firms in the stratified sampling frame and 14.7% of the 360 firms in the whole population of the 1994 UNDP database of electronics firms in Klang Valley and 1994 Penang Development Corporation database. In terms of location, they represent 12.5% and 17.5% of the whole population of firms in the Klang Valley and Penang, respectively. In terms of sales, the 1998/9 combined sales of the 53 sampled firms is about US$8.5 billion or close to 30% of manufactured electrical machinery and electronics products exports in 1997.

Table 2. Sample composition: groups, firms and location

Location	Group 1: TNCs subsidiaries						Groups 2 and 3: local firms	Totals
	USA	Europe	Japan	South Korea	Taiwan	Total		
Klang Valley	0	2	10	0	1	13	12	25
Penang	7	2	3	0	1	13	15	28
Sub-total	**7**	**4**	**13**	**0**	**2**	**26**	**27**	**53**
Manaus	2	3	8	3	0	16	13	29
Totals	**9**	**7**	**21**	**3**	**2**	**42**	**40**	**82**

The Manaus sample derived from search into the archival records of the Superintendency of the Manaus Free Trade Zone (SUFRAMA) – Ministry of Development, Trade and Industry – and the Centre of Industries of the Amazonas State (CIEAM). The sampled firms hold about 90% of the manufacturing volume and about 90% of market-share in the consumer electronics industry in Brazil. They represent more than 80% of the population of electronics firms in Manaus. Additionally, in 2000 the electronics sector in Manaus generated more than 50% of employment and more than 40% of the total revenue of the Manaus Free Trade Zone that was US$10.4 billion.

3.2 Data collection and analysis

The data collection in Malaysia and Manaus was implemented in three phases (Table 3). In each of these phases, in-depth interviews, casual meetings, and direct-site observations were used as strategies for collecting primary empirical evidence. These were carried out with directors, managers, engineers, technicians, crew supervisors and even operators. Additionally, firms' publications in the form of report, brochures, books, videos and other sources (firms' websites, press reports) were also collected as sources of secondary empirical evidence. Face-to-face interviews were conducted with senior management involving the managing director, plant or production manager and those involved with innovative activities: R&D, design, engineering, quality and maintenance department managers and technical staff. These were followed by observation tours across plant and production support units. The original data were initially entered into an Access database since it allowed qualitative interview data to be inputted as memo and text data. To allow statistical analysis to be conducted more efficiently, most of the qualitative text and memo data were converted into quantitative data according to the statistical package SPSS 9.0 format. Previous qualitative data on firms' activities were quantified according to the various categories of Table 1. To analyse the data, both qualitative and statistical analysis were conducted. For qualitative analysis, the technological capability-building paths of all 53 sampled firms in Malaysia and 29 firms in Brazil (Manaus) were traced out and graphed. For the statistical analysis, non-parametric statistical tests were used since levels and types of technological capabilities consisted of ordinal measurement.

Table 3. Phases of fieldwork in Malaysia and Manaus

Phases	Location	Time period	Activities
Phase 1	Malaysia	Preliminary stage (August to September 1994)	*UNDP-USM Questionnaire*: mailed to 200 firms in Klang Valley; 30 correct returns. *Stratified sampling* of three strategic groups: First-tier TNC subsidiaries (group 1), local dependent suppliers or linkage firms (group 2), and local independent firms (group 3) for the main fieldwork.
	Manaus	Exploratory phase (November 1999)	The implementation of this phase sought to confirm the feasibility of the study and open up access to some firms. Nine firms and three institutions related to the electronics industry were interviewed.
Phase 2	Malaysia	Main fieldwork (intermittently from September 1994 to February 1996)	*Face-to-face interviews and plant visits*: Follow-up interviews were possible with 26 of the 30 firms from Phase 1;Added interviews with 28 firms in Penang; Collection of secondary data.A total of *53 firms* researched and visited were included in the final sample for analysis.
	Manaus	Pilot work (July 2000)	22 firms were researched. Each interview was followed by a tour around the plant.
Phase 3	Malaysia	Refining and update data (from January 1996 onwards)	*Supplementary Questionnaire*: mailed to 53 researched firms; 6 correct returns. *Data updates till March 2002:* Interviews (and plant visits) with four local and six TNC subsidiaries from Jan-March 2002, visits to electronics exhibitions (NEPCON 2001 and 2002, Metal Tech 2002) and secondary sources.
	Manaus	Main fieldwork (October-November 2000)	In-depth interviews with managers, engineers, technicians of 29 sampled firms. Each interview took, on average, two hours and was followed by tours and direct observation. During this phase, evidence gathered during pilot work was validated within each firm.

4. Technological capability building in the sampled firms

This section focuses on the types and levels of capabilities that have been developed in the sampled firms. Using the framework in Table 1, the incidence of sampled firms at specific types and levels of technological capabilities, by the time of the research, is indicated in Table 4.

4.1 Evidence from Malaysia

In terms of capability level, regardless of activity type, Table 4 shows that 43 (or 81%) of the leading electronics firms researched in Penang and the Klang Valley are located between Levels 4 and 5 innovative capability. Thus, the first null hypothesis in Section 3 can be rejected to some extent. Even though there are only two firms conducting research-based innovative activities, more than 50% of firms (27) have reached Level 4 capability, while more than 30% of firms (16) have reached Level 5 advanced capability. Additionally, all 53 firms have mastered basic operations in process and production organisation, product-centred activities, and capital equipment, tooling and moulding. The findings also show that there is a steady progression in the trajectory involving the production of increasingly complex and higher-value products, and the relocation of analogue, and more labour-intensive consumer electronics to cheaper and more labour-abundant locations. From 2000, local and TNC subsidiary component suppliers have started to progress into higher value-added and more precision component manufacturing requiring micron and sub-micron precision levels. Ten firms researched in 2002 were found to be progressing from the assembly and testing of electronic and semiconductor devices to the sub-assembly and component assembly of more complex optics and photonic devices, MEMs, organic flat panel displays, and the manufacture of components for scientific instruments (biotechnology and medical). During the launch, MPEG had an initial membership of 50, mostly firms and researchers. Comparison between the different types of technological capability shows that, in terms of capability for process and production organisation, six firms (11.3%) were found at Level 2, whereas 17 firms (32.1%) were found at Level 3. In relation to product-centred capability, nearly 25% of firms (13) were found at Levels 2 and 3. These findings are consistent with conventional expectations about ‘process or continuous innovation’ capability in the production process, and ‘product adaptation or modification’ capability in firms in late-industrialising countries.

4.2 Evidence from Manaus

Considering the development of innovative capability levels regardless of activity type, Table 4 shows that 93% of the sampled firms have developed innovative technological capabilities. In other words, most of the sampled firms have developed capabilities between Levels 3 and 5. Seven firms (24.2%) have developed advanced technological capabilities (Level 5). Only two of the sampled firms, have been confined to basic operations capability, although at Level 2. No sampled firm was found confined in Level 1. More specifically, in terms of capability for equipment, tooling, stamping, and moulding, seven firms (24%) were found at Level 2, while 22 firms (76%) were found at Levels 3 and 4. These have being able to carry out, independently, activities such as: development of own testing jigs & burn-in equipment, re-engineering, own development automatic sensors in conveyor systems, vision for testing; mechanical, pneumatic devices to speed process flow; automated movement of incoming, work-in-progress (WIP) and finished goods; patents: own developed automated test equipment and multi-product testing software tools (own TestCAD), fairly precision plastics moulding and mould modifications for consumer electronics and telecommunications products. With respect to capability for project management, six firms (20%) were found at Level 2, while 23 firms (nearly 80%) were found at

Table 4. Incidence of firms at specific types and levels of technological capability by the time of the research

Types and levels of technological capability	Capability level, regardless of activity type		Project management		Equipment, tooling, stamping, moulding		Process and production organisation capability		Product-centred activities	
	Malaysia	Manaus	Malaysia	Manaus	Malaysia	Manaus	Malaysia	Manaus	Malaysia	Manaus
ROUTINE PRODUCTION CAPABILITIES: CAPABILITIES TO USE AND OPERATE EXISTING TECHNOLOGY										
Basic operation Level 1	0	0	17 32.1%	0	0	0	0	0	0	0
Basic operation Level 2	0	2 6.9%	6 11.3%	6 20.7%	19 35.8%	7 24.1%	6 11.3%	0	13 24.5%	11 37.9%
INNOVATIVE TECHNOLOGICAL CAPABILITIES: CAPABILITIES TO GENERATE AND MANAGE TECHNICAL CHANGE										
Basic Innovative capability Level 3	8 15.1%	5 17.2%	17 32.1%	16 55.2%	14 26.4%	15 51.8%	17 32.1%	6 20.7%	13 24.5%	13 44.9%
Intermediate innovative capability Level 4	27 50.9%	15 51.7%	11 20.8%	7 24.1%	14 26.4%	4 13.8%	20 37.7%	17 58.6%	17 32.1%	4 13.8%
Advanced innovation Level 5	16 30.2%	7 24.2%	2 3.8%	0	6 11.3%	3 10.3%	9 17%	6 20.7%	9 17%	1 3.4%
Research-based innovation Level 6	2 3.8%	0	0	0	0	0	1 1.9%	0	1 1.9%	0
Totals	53 100%	29 100%	53 100%	29 100%	53 100%	29 100%	53 100%	29 100%	53 100%	29 100%

Source: Derived from the research.

Levels 3 to 4, that is, firms have been engaged in activities such as: systems integration, provision of customised software solutions, and software development. In relation to capability for process and production organisation, the study has found that all firms (100%) have developed innovative capabilities for process and production organisation at Levels 3 to 5, in other words, 20% at Level 3; 59% at Level 4; and 20% at Level 5. In terms product-centred activities, 18 firms (62%) have developed product-centred capabilities at Levels 3 to 5: 45% at Level 3; 14% at Level 4; and 3% at Level 5.

4.3 Related technological development indicators

This section examines the extent to which related indicators of technological development – local decision-making, automation level, and export performance – are associated with the capability levels examined in Sections 4.1 and 4.2. Table 5 shows that automation, local decision-making and control are significantly associated with technological capability levels of firms. On the other hand, percentage of export, region (i.e. whether firms operate in Penang, Klang Valley and Manaus) and group (whether firms are Groups 1, 2 and 3) are not significantly associated with technological capability levels of firms.

Table 5. Kruskal-Wallis test for related technological development indicators

	Group	**Region**	**Local decision & control**	**Automation level**	**% Export**
Chi-Square	5.165	4.043	26.982	18.256	2.503
df	4	4	4	4	3
Asymp. Sig.	.271	.400	.000***	.001***	.475

(a) Kruskal Wallis Test; (b) Grouping Variable: TCLEVEL

4.3.1 Automation Level

Automation level is a widely used and quite relevant measure in the production function of many electronic goods and components, particularly in the semiconductor and hard disk drive sectors (e.g. Noor, 1999). However, unlike many other studies and arguments on technological capability that assumes a direct link between automation and innovative capability level, in this paper, automation level is an independent measure. This is because we differentiate between production operation and innovative activities. In addition, there are examples of firms in this research, particularly in the highly automated hard disk producing and CD-Rom drive sectors, that have highly automated production operations, but have relatively low innovative capabilities to change processes and products. Also, there are firms that design software systems or design application specific ICs (ASICs) that have relatively high levels of innovative capabilities, but only do manual final assembly in the production of its electronic goods because most of the production process is outsourced. Thus, due to these inconsistencies, automation is treated as an independent measure, and is tested as to whether it is related to innovative capability level. In relation to the Malaysian sample, Table 6 shows that only seven of the 53 researched firms use fully manual operations, involving conveyors for manual assembly of parts and products. Thirty-five firms (66%) have between 20-50% automation level. Eleven firms have 'hands-free' production operations that are fully automated, usually involving a relatively large number of SMT machines, robotic arms and robots, automated movement of work-in-process goods, or/and computer-integrated manufacturing (CIM). With respect to the Manaus sample, Table 6 shows that only three of the 29 sampled firms use fully manual operations, consisting of conveyors for manual assembly of parts and products. Nine firms (or 31%) have between 20-30% automation level, while 13 firms, have approximately 50% automation level. Four firms (14%) have 'hands-free' production operations that are fully automated, usually involving a relatively large number of SMT machines, robotic arms and robots, automated movement of work-in-progress goods, or/and computer-integrated manufacturing.

Table 6. Automation levels in the sampled firms

Automation Level	Number of firms	
	Malaysia	Manaus
Manual	7 (13%)	3 (10.%)
20 – 30% of automation	12 (23%)	9 (31%))
~50% of automation	23 (43%)	13 (45%)
Full automation or computer integrated manufacturing (CIM)	11 (21%)	4 (14%)
Total of firms	53 (100%)	29 (100%)

Source: Derived from the research

The statistical results of the 53 firms in Malaysia suggest that automation level is positively correlated to innovative technological capability (rho=.393, p<.01), specifically for TNC subsidiaries (rho=.339, p<.01) and local independent firms (rho=.649, p<.01). However, it is not significant for local firms (suppliers). It may be because these firms are smaller in terms of sales and employee size and, thus, would not have the necessary resources to invest in high levels of automation. Nevertheless, these firms have been able to be innovative using available equipment that may not be as highly automated as the other types of firms. The statistical results of the 29 firms in Manaus also suggest that automation is highly correlated to innovative technological capability (rho=.602, p<.01). This is because most of the automation is the result of innovations developed in-house, or in-collaboration with equipment suppliers, software firms, or university students and professors. This is especially prevalent in the area of material handling, such as automated conveyor systems with real-time sensors linked to the manager's desk, ingenious conveyor designs that link from one plant to the next, automated assembly and movement from in-coming raw material to assembly to packaging of finished goods, and flexible lines that minimises lead time and accommodate multiple models. A second area of innovation for automation is in redesigning robots used in other industries (e.g furniture) and adopting the production organisation of flexible, one-man production cell used in consumer electronics and multi-functional robot cells that can process the raw material to produce a finished product. A third area of innovation for automation is in testing, such as the development of automated multi-product line testing software tools and jigs (patented and sold to sister plants worldwide), and burn-in rooms with automated sensors.

4.3.2 Local decision-making and control

This indicator examines local management's capability for decision-making and control. The capability for independent local management, i.e., without foreign management, has been frequently raised by other studies and government reports. In this research, sampled TNC subsidiaries were found to have varied levels of local management control over procurement, pricing, product development, recruitment, training, distribution and marketing. At the lowest level, local staff hold very few managerial positions, with positions limited to those related to recruitment and training of operating staff, and supervision of routine operations (see Table 7).

4.3.2.1 The Malaysian sample

The 26 TNC subsidiaries researched were found to have varied levels of local management control over procurement, pricing, product development, recruitment, training, distribution and marketing. At the lowest level, local staff hold very few managerial positions, with positions limited to those related to recruitment and training of operating staff, and supervision of routine production operations. However, only two of the 26 TNC subsidiaries researched were observed to be at this level.

Table 7. Levels of local decision-making and control in sampled firms

Level of local decision-making and control	Actual examples of activities to indicate local decision-making and control	Number of firms	
		Malaysia	**Manaus**
Limited or passive role & capability (Level 2)	Recruitment of production workers, human resource training. Supervisory of assembly and routine operations.	3 5.7%	3 10%
Basic active role and capability (Level 3)	Active monitoring and control of technology choice and sourcing of equipment or material. Direct material procurement. Vendor development programme to identify and train local suppliers. Senior management positions by locals.	18 34%	11 38%
Intermediate active role and capability (Level 4)	100% local management. Direct customer interface. Assume wider responsibility over conceptual planning, product development, marketing and distribution.Local managing director, a 100 per cent local management, or local staffs seconded to head world-wide facilities.	15 28%	13 45%
Advance active role and capability (Level 5)	For TNC subsidiaries, this meant that local staff has responsibility over the start-up and management of new large investments, production plants or subsidiaries, either in the country or overseas.	17 32%	2 7%
Total number of firms		**53**	**29**

Source: Derived from the research.

4.3.2.2 The Manaus sample

Differently from the firms in Malaysia, where many of the managing directors are foreign nationals from TNC parents, more than 90% of the TNC subsidiaries and joint ventures in Manaus are headed and managed by Brazilian nationals, particularly from São Paulo and Southern Brazil. Twelve of the sampled 29 firms (41%) have at least basic active role and capability in local decision-making and control. For these firms, the local staff has a more active role in monitoring and control of choice and sourcing of non-complex or older vintage parts and equipment (e.g. conveyors). This is usually initiated by the setting-up of a specific procurement decision. At this level, local staff and engineers interact with suppliers to modify old vintage designs and specifications to mechanise and fabricate cost-effective parts and equipment.

4.3.3 Export performance

This section briefly presents a few comments related to why the percentage of exports is not significant to innovative technological capability. Indeed, percentage of export is not a significant factor when we combined the Manaus and Malaysian samples (82 firms) because of the large difference in export percentage between Malaysian and Manaus firms. That is, even the most innovative firms in Manaus only export about 50%, while in Malaysia even the least innovative firms export 60% because of the 85% export requirements of the free trade zones and licensed manufacturing warehouses in Malaysia. Firms that export less than 85% of sales are suppliers to customers in the free trade zones or market to the domestic market. Thus, that is why, when both samples are combined, export percent does not significantly affect innovative capability. However, when we tested percent of export for each sample (within Malaysian and Manaus samples), this factor is significant for both samples. Within the Malaysian sample, export levels were highly significant, and also within the Manaus sample, export levels were highly significant to innovative capability. Thus, the significance of the finding is that innovative capability is not dependent on whether firms operate in a historically 'import-substitution' industrial policy region like Manaus or whether firms operate in an export-oriented country like Malaysia (and other East Asian countries). In other words, the findings show that it does not matter if firms had been operating within these different industrial policy countries – contrary to what has been argued elsewhere (e.g. Hobday, 1996, on East Asia).

5. Conclusions and implications for policy

This paper has focused on the development of types and levels of technological capabilities in the electronics industry in a late-industrialising country like Malaysia and in a developing area like Manaus. In doing so, this paper has moved a step forward in relation to the debate of internationalisation of innovative technological capabilities by examining detailed empirical evidence that tends to be ignored in the existing literature. Key contributions of the paper are reviewed below.

1. This paper has provided counter evidence to the generalisations mentioned Section 1. In other words, it has been found that the technological capability of most TNC subsidiaries and local firms in Malaysia and Manaus, far from being static and confined to very basic levels for long periods, has constantly been upgraded to carry out diverse types of innovative activity. Additionally, it has been shown that these capability-building efforts are strongly associated with higher capability for local decision-making and control, automation level, and with efforts to increase exports. That is, the common generalisations relative to technological development in Malaysia and Manaus, mentioned in Section 1, are misleading.
2. Indeed, we have found pockets of innovative firms that innovate to be competitive by reducing costs, being more productive, reducing lead-time, producing better products that consumers want – regardless of whether they are in an import-substitution country or in an export-oriented country. However, within those regions, export is an important factor that drives firms to be compete against other global players, thus, more innovative to reduce costs, more productive to maximise yield, reduce lead time, reduce ramp-up time (from product design to full production). This is what is important about our comparative research on Manaus (Brazil) and Penang and Klang Valley (Malaysia).
3. Our research has applied a much more systematic and comprehensive framework to measure capabilities and activities that take place in firms in the electronics industry in late-industrialising countries and areas (Table 1). It provides an alternative to the two sets of existing available measures – patent statistics and R&D expenses – that have commonly been used as a proxy for technological activity in the literature on the internationalisation of innovative activities and in arguments about local technological development. Since these proxy indicators tend to focus only on activities at the highest technological level, the rest of the bulk of technological activities tends to be ignored. Thus, for the Malaysian and Manaus electronics industry that is dominated by production-based subsidiaries of global TNCs, they are not likely to attain the highest level of product development and R&D, as these activities are retained in corporate R&D centres or carried out in advanced and historically established R&D locations. Nevertheless, there is still very little detailed account of what actually entails technological activity in subsidiaries in a less developed location. In addition, for firms in late-industrialising countries, that usually start operations without even sufficient basic levels of technological capability, using conventional proxy indicators would not measure whether firms have increasingly built up higher capability levels.
4. Although this paper has not been structured to address policy measures, it sheds some light on some of the perspectives that underlie common approaches to policy. First, the use of a framework that explicitly identifies different types and levels of industrial technological capability is useful in drawing attention to the extremely important types and levels of technological capabilities that are concerned with neither routine production nor 'R&D'. As noted above, this paper suggests that a very large part of the process of technological development in the Malaysian and Manaus electronics industry, during the last 25 years, has been concerned with building and using these commonly neglected capabilities. That long and important phase of technological learning is evidently a precondition for entry into R&D-based innovation. Second, it is important to distinguish between two fundamentally different dimensions of technological development: (i) movement through increasingly 'advanced' and

complex products and processes and (ii) movement through increasingly creative roles in connection with those product/process technologies (e.g. from their basic operation and use through various kinds of design and engineering to differing 'depths' of R&D). Progress along these two dimensions involves the creation of very different kinds of resources and the use of different learning mechanisms. Thus, while governments may have interests in accelerating both types of progress, different measures will be necessary in each case.

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