University of Oxford

Department of International Development

SLPTMD Working Paper Series

No. 009

Government policy, firm-level capabilities, and knowledge linkages: An alternative view based on empirical evidence from Brazil

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An alternative view based on empirical evidence from Brazil

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Abstract
Although much has been written about the implications of the structural reforms of the 1990s for industrial progress in developing countries, particularly in Latin America, less attention has been given to the role of meso and micro factors in sector and firm-level technological capability building. Most existing studies are based on aggregated analyses that argue either *for* or *against* such reforms. Seeking to offer an alternative view on this debate, this paper examines firm-level capabilities in association with inter-organisational knowledge links (as sources of such capabilities) in the light of government policies. The paper draws on first-hand empirical evidence from a sample of 75 organisations (46 firms and 29 innovation system supporting organisations) in Northern Brazil. The study found a diversity of firms' capability types and levels and a variety of sources to build up and/or sustain such capabilities (knowledge links). Overall, firms and the local innovation system have been exhibiting a positive response to those structural reforms, but such responses were not a mere consequence of trade openness. Indeed, the evidence here does not support a Washington Consensus-type of argument; neither does it suggest a return of the ISI strategy. Instead, a combination of government policy, foreign competition, firms' capability building efforts, and the emergence supporting organisations in the local innovation system has been proving essential for innovative capability accumulation in some of the sampled firms. Thus policies for accelerating industrial technological capability building in a developing area such as the one examined here should involve not only macro-level incentives and competition, but, very importantly, measures that facilitate and stimulate intra-firm capability building efforts.

Key words: Government policy; industrial policy regimes; firm-level capability, knowledge links, Brazil.

Acknowledgements
I feel honoured for having benefited from Sanjaya Lall's insightful and encouraging comments on the research underpinning this paper. I dedicate this paper to his memory. I have also benefited from positive and challenging comments during the Meeting of Experts on 'FDI, Technology and Competitiveness – A conference convened in honour of Sanjaya Lall', especially from Richard Nelson, Jorge Katz, Raphael Kaplinsky, Carlo Pietrobelli, Carl Dahlman, Francisco Sercovich, and Rajah Rasiah. Also, I am grateful to Martin Bell for continuously inspiring me to improve my research in this field. Very special thanks go to all companies that have participated in the fieldwork for this research and to Marcela Cohen for her invaluable research assistance. I thank the Brazilian Government Ministry of Development, Industry and Foreign Trade for sponsoring this research. The usual disclaimers apply.

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1. Introduction

Over the past few years we have witnessed the emergence of polarised views of the implications of the structural reforms of the 1990s for industrial development in several developing countries, especially in Latin America. On the one hand, from a Washington-consensus perspective, it was advocated during the early 1990s that trade liberalization *per se* would lead to industrial progress economic growth, and competitiveness (World Bank, 1993). In line with such argument, but from diverse standpoints and at differing degrees, some studies suggested positive implications of such changes for industrial performance either in a sample of countries (e.g. Edwards, 1998) or in specific countries such as Chile (Tybout et al., 1990; Crespi, 2006), Colombia and Bolívia (e.g. Robert & Tybout, 1991), Mexico (e.g. Tybout & Westbrook, 1995), and Brazil (e.g. Moreira & Correa, 1998; Hay, 2001; Ferreira & Rossi, 2003). Most of the studies, however, have focused mainly on industrial performance indicators, but not on firm-level technological capability building.[1] On the other hand, there are studies that are sceptical on the effects of trade openness on industrial growth (e.g. Rodríguez & Rodrik, 2000), with some arguing that the shift from an inward into an outward-looking policy regime have had negative impacts on the existing industrial technological capabilities in Latin America (e.g. Ocampo, 2001; Narula, 2002; Cimoli & Katz, 2003 among others).

Nevertheless, as pointed out in Westphal (2002) and Lall (2003, 2006), while it may be true that trade liberalization may help prevent some egregious forms of intervention like the protection of the 1970s and 1980s, the alternative of persisting with wholesale liberalisation is

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[1] In such studies 'technical efficiency' is tackled on the basis of conventional indicators such as research and development (R&D) expenses as a proportion of GDP or the number of patents granted to firms by the US Patent and Trademark Office (USPTO). Although such indicators may capture some aspects of innovative activities, in most situations they are not adequate for measuring such innovative activities in the context of late industrialisation (see, for instance, Lall, 1990, 1992; Bell & Pavitt, 1993; Ariffin, 2000; Figueiredo, 2001, 2006).

also likely to prevent developing countries such as those in Latin America from speeding up their technological development. However, as most of the existing studies on the impact of the structural reforms of the early 1990s on latecomer industrial development are based on aggregated analysis, a firm-level empirical scrutiny of technological capability development, drawing on a proper analytical framework within the context of changes in policy regimes, is still largely missing in the literature.

Indeed, the rate of technical progress of a country depends not only on the state of economic fundamentals, but also on a host of sector- and firm-specific forces (Katz, 2004). Such forces need to be examined in order to explain why some firms and industries forge ahead, while others fall behind in terms of capability accumulation and innovative performance (Bell & Pavitt, 1993; Amsden, 1994; Katz, 2004). However, as pointed out in Katz (2004: 378): 'much less attention has been given to the role of meso and micro factors in sector and firm-level technological and innovative performance'.

This paper seeks to offer a contribution in that direction. Indeed, it does not seek to engage in the polemics of an inward-looking *versus* outward-looking policy regime. In a recent paper I examined the issue of firm-level capability development in the light of changes in policy regimes in Brazil using, as a primary source of analysis, firm-level and first-hand empirical evidence from Northern Brazil (see Figueiredo, 2007). Moving a short step further, and drawing on the same empirical setting and sampling, this paper takes up the task of examining some of the key sources to build up and/or sustain those firm-level capabilities, i.e., two different types of knowledge linkages: (i) inter-firm knowledge linkages (links established between sampled Brazilian and TNC-subsidiaries in Manaus with their parent firms elsewhere and links between local producers and local suppliers); and (ii) inter-organisational knowledge links (links set up between the sampled firms and local innovation system supporting organisations (e.g. universities, research institutes, consulting firms, training centres).

These issues are examined on a relatively small sample of 46 firms (local firms and TNC-subsidiaries drawn from three sectors: electro-electronics (hereafter EE)); motorcycles and bicycles (hereafter MCB) and key suppliers and 29 organisations of the local innovation system. One of the limitations of this paper is that it is based on one-country and one-region perspective and the paper draws on a relatively small sample of organisations. Additionally, while the issue of technological capability is examined on the basis of a long-term coverage, the issue of inter-firm knowledge links is covered only from 2001, whereas evidence of links between sampled firms and organisations of the local innovation system refers only to the time of fieldwork, thus, its treatment here is static.

This paper is organised as follows. Section 2 presents the analytical framework in the light of which the evidence of this study is examined. The empirical setting in which the study was developed is briefly outlined in Section 3, whereas the research methods are described in Section 4. The empirical analysis, discussions, and a summary of key findings are presented in Section 5. Finally, Section 6 presents the paper conclusions and policy implications.

2. Analytical frameworks

2.1 An assimilation perspective on industrial development

Industrial development in late-industrialising countries is normally examined from different perspectives such as ‘accumulation’ and ‘assimilation’ theories. While the former stresses the role of high investments rates in physical systems and human capital in achieving development, the ‘assimilation’ perspective recognizes the importance of such investments, but sees learning, capability building, and innovation as central factors in explaining industrial growth (Nelson & Pack, 1999).

Such view is in line with the ‘evolutionary perspective’ on firms’ technological activities (Rosenberg, 1982; Dosi et al., 1994; Nelson & Winter, 1982; Nelson, 1991; Metcalfe, 1993), in the light of which the firm is viewed as a dynamic organisation and as a repository of productive knowledge that distinguishes it even from similar firms in the same line of business (Winter, 1988). This would explain the diversity that one is likely to find when investigating firms’ technological activities, even those that have evolved under the same economic conditions. Such differences are associated with the nature of the innovative process that is firm-specific, path-dependent, uncertain, and cumulative (Dosi, 1988; Nelson, 1991; Pavitt, 1991).

This paper takes the view that the building of technological capability is a basic problem of latecomer firms as they normally start from a condition of being uncompetitive in the world market (Bell et al., 1982). As firms do not operate in a ’vacuum’, their internal capability building efforts are affected by external factors such as the industrial policy orientation. As argued in Bell et al. (1982), ‘a firm’s technological behaviour can be seen as a set of responses to stimuli in its environment’. As far as policy regimes are concerned, there is a relationship between the degree of protection and both learning and pattern of technological behaviour (Bell, 1984). It has been suggested that the more the competitive pressure and rivalry, the greater are the incentives for technological accumulation (Dahlman et al., 1987; Bell & Pavitt, 1993).

Indeed, as Lall (1992) pointed out: 'inward-oriented regimes foster learning to "make" do with local materials, "stretch" available equipment, and down-scale plants, while export-oriented regimes foster efforts to reduce production costs, raise quality, introduce new products for world markets and often reduce dependence on (expensive) imported technology.' It is in the context of such a framework that this article examines the extent to which the main changes in policy regimes in Brazil are reflected in the pattern of firm-level technological capability building in the sampled firms from Manaus (Northern Brazil). Thus, this paper draws on existing frameworks for examining firms' technological capabilities in association with key sources of to build and sustain such capabilities: (i) knowledge links they establish with other firms in their corporate group and their suppliers; and (ii) inter-firm organisational knowledge links that they set up with supporting organisations of the innovation system. The frameworks for examining these issues are outlined below.

2.2 A framework for measuring firms' technological capabilities

Technological capability is defined here as the resources needed to generate and manage technological change. They are accumulated and embodied in skills, knowledge, experience and organisational systems (Bell & Pavitt, 1993, 1995), which is in line with earlier definitions of the term (e.g. Bell et al. 1982; Dahlman & Westphal, 1987; Katz, 1976, 1987; Lall, 1992, 1994). By adopting such a comprehensive view on technological capability the study underpinning this paper seeks to capture and assess a wider range of firms' *innovative* capabilities rather than on R&D and patenting capabilities or production capabilities alone.[2]

In order to operationalise such view, technological capability is examined here on the basis of a Sanjaya Lall type of taxonomy. Adapted from Lall (1990, 1992) and Bell & Pavitt (1995),

[2] For a review of the limitations of such conventional indicators to measure firms' technological capabilities in the context of late industrialisation see Bell & Pavitt (1993), Ariffin (2000), Figueiredo (2001), Ariffin & Figueiredo (2004).

such typology makes a relatively fine disaggregation between two major types of capability: (i) 'routine capability' or capability to use and/or operate existing technologies and production systems; and (ii) 'innovative capability' or capabilities to carry out changes in technologies and production systems, in a independent manner.

To examine technological capability development in this study, such taxonomy has been tailored for electro-electronics firms and suppliers (see Appendix A) and for bicycle and motorcycle firms and suppliers (see Appendix B). The columns set out the technological capabilities by function; the rows, by levels of difficulty. They are measured by the type of activity expressing the levels of technological capability, that is, the type of activity the firm is able to do on its own at different points in time.[3]

This fine disaggregation between 'routine' and 'innovative' capabilities is important to understand the extent to which firms move from production-based into innovation-based activities over time, which is extremely relevant to the understanding of the process of technological accumulation in latecomer firms (Lall, 1992, 1994; Hobday, 1995; Bell & Pavitt, 1993, 1995). The application of such framework also permits to examine the extent to which – and the pace at which – firms move through different 'stages' or levels of innovative capabilities – from basic to intermediate levels up to advanced capability levels. On the hand, this is line with a comprehensive view on innovation that involves imitation, adaptation, improvement, experimentation and also design and development activities based on R&D levels and patenting (Nelson & Winter, 1982; Dosi, 1988). Additionally, such basic and intermediate levels of innovative capability are a pre-condition to achieve advanced innovative capability levels (Bell & Pavitt, 1995, 1993). Thus, evidence on the movement of

[3] The framework for firm-level technological capability in the electro-electronics industry had previously been applied in empirical studies in Malaysia (see Ariffin, 2000) and Brazil (see Ariffin & Figueiredo, 2004).

firms through such innovative capability levels – for specific technological functions – is important to provide us with a nuanced and dynamic perspective on the firm-level technological accumulation process in order to inform corporate strategy and policy makers.

2.3 A framework for examining inter-firm knowledge links

This paper draws on the framework developed in Ariffin (2000) to examine inter-firm technological learning links between (i) TNC subsidiaries and parent firms (subsidiary-parent links) and (ii) suppliers and producer firms (local and TNC subsidiaries) – supplier-customer links (see Table 1 below). Ariffin's (2000) framework proves helpful to capture and examine such kinds of relationships which have seldom been captured within the late-industrialising literature.

Table 1. Framework for inter-firm knowledge links

	Links centred on market transactions in goods and services	**Technological (knowledge) learning links** **Existing Technology** **(Routine Production)**	**Innovation Links**
<u>CAPABILITY-</u> ***<u>USING</u>*** **LINKS**	**MP-Links** In these Marketing/Production links, interactions between firms is a purely marketing relationship involving the sale of goods and services derived from the use of existing production capabilities, and involving no significant elements designed to create or enhance those capabilities.		**I-Link** In these Innovation links, interaction is the source of innovation. Here firms already have innovative technological capabilities, and they collaborate in using those to execute innovation, usually involving collaborative Research, Development and Design for new products and processes.

CAPABILITY- ***BUILDING*** **LINKS** **(LEARNING LINKS)**		**LP-Link** These Learning for Production links are used by firms to create or enhance basic production capability. Usually one of the firms draws on the other to build up a basic capability to produce particular products, to use particular processes, and/or to master specific managerial and organisational practices.	**LI-Link** Through these Learning for Innovation links, firms build up new basic and intermediate level innovative capabilities. This may involve training and formalised experience acquisition, together with less formally organised learning through reverse engineering and incremental improvement.

Source: Ariffin (2000)

The typology, which organises knowledge flows and learning links between firms involves a combination of two distinctions (Ariffin, 2000): (i) links that are primarily concerned with market transactions for goods and services, and (ii) links that are concerned with knowledge flows. Specifically, the focus on different knowledge flows and learning links – from market transactions (MP-links), learning-for-production (LP-links), learning-for-innovation (LI-links) to innovation-centred links (I-links) – are useful in clarifying the different technology-related interactions between these firms. As pointed out in Ariffin (2000), in much of the innovation-related analysis of user-producer links in industrialised countries, and in the associated analysis of technology-centred interactions running along supply chains in those economies, it is suggested that these two kinds of relationship may overlap. However, it is fairly obvious that they may also be quite independent. On the one hand, innovation-centred strategic alliances, for instance, may be developed between firms that are not involved in significant supplier-customer relationships. On the other, an enormous number of inter-firm relationships involve market transactions in goods and services with no associated collaboration in innovation.[4]

[4] For more details of such framework see Ariffin (2000).

Secondly, the typology distinguishes between: (i) links primarily based on the use of *existing capabilities* that firms already possess, and (ii) links that contribute significantly to *creating such capabilities*. The first may occur between firms when market transactions for goods and services involve little or no associated skill and knowledge transfer that enhances pre-existing technological capabilities of firms. On the other hand, links with other firms may involve substantial flows of knowledge and skill in order to build up higher or new capabilities in firms, either operation-based or innovative technological capability (Ariffin, 2000).

2.4 A framework for linkages between firms and innovation system supporting organisations

Supporting organisations of the innovation system involve several and different agents (such as universities, research and technology institutes, technical schools, consulting firms, incubators). Linkages set up between supporting organisations and industrial firms are not linear. In turn, firms’ innovative process is not homogeneous – it takes diverse forms and makes use of different sources of knowledge – varying with several characteristics of firms themselves and depending on the stage of technology development in specific sectors and on the firms' capacity to cope with that development. In order to explore these interactions this paper draws on the taxonomy developed in Vedovello (1995) as outlined in Table 2.

Table 2. Framework for knowledge linkages between firms and innovation system supporting organisations

Types of links	Definition	Details/examples
Informal links	Through this set of links, firms, in their search for technical solutions or in their attempt of implementing an innovation, establish contact with the pool of information and knowledge, expertise and equipment available at organisations linked to the technological infrastructure (e.g. universities, private or public research institutes, training centres, consulting firms). On the other hand, organisations linked to the technological infrastructure establish contact with firms and their technical and scientific capabilities and needs. The establishment of these links does not imply formal contracts between the partners, even though small fees may sometimes be involved on an *ad-hoc* basis.	1. Informal contacts with researchers/business people 2. Access to specialised literature 3. Access to the research of specific departments 4. Participation in seminars and conferences 5. Access to equipment of research institutes and universities and/or firms' research institutes 6. Participation in specific programmes (education and training) 7. Other informal-related links
Human resources	These are related to the improvement, training and recruitment and/or allocation of qualified manpower. Firms, for instance, may wish to strengthen their links with organisations linked to the technological infrastructure through the support to, or absorption of, qualified people. This group of links also extends the possibilities of promoting technical and continuing education in specific areas of firms' interests. From the perspective of the organisations linked to the technological infrastructure, individual researchers or a specific unit may wish to strengthen their links with companies seeking (i) to increase the supply of jobs for their qualified people; (ii) to extend the educational basis and their research portfolio. This group of links also broadens the possibilities of providing more structured training to firms' employees and research staff.	8. Involvement of students with industrial projects 9. Recruiting of newly graduate 10. Recruiting of experienced scientists and engineers 11. Formally organised training programmes to meet human resources needs. 12. Other human resources-related links
Formal links	Through this set of links, firms, being aware of the resources available at organisations linked to the technological infrastructure – knowledge and information, human resources and equipment – may wish to contract the use of equipment or to contract research projects, in an individual or collective basis, or develop joint research to support and complement their internal technological effort. From the perspective of the organisations linked to the technological infrastructure, after being familiar with the industrial environment and its technical and scientific capabilities, they may wish to use industrial equipment or to offer their scientific expertise to firms and consequently enlarge their income and broaden their research portfolio through the development of contract research or joint research. Usually, these links implies the set-up of formal contracts between the partners, with both the commitment and the payment of fees previously established.	13. Consultancy developed by researchers or consultants 14. Analysis and tests (technical trials) 15. Services for records updating (updated technical norms, patents). 16. Technical responses (e.g diagnostic of problems in terms of production process). 17. Signing up of research contracts (e.g. software development) 18. Establishment of joint research 19. Other formal-related links

Source: Adapted from Vedovello (1995).

The framework identifies three types of links that are organised in three groups: (i) informal links (small fees may sometimes be involved on an *ad hoc* basis); (ii) human resource-based links (training and education activities), and (iii) formal links (for these two groups of links, the commitment and the payment of fees are, usually, agreed in advance).

3. The empirical setting

The Industrial Pole of Manaus started up in 1967 under the import-substitution industrialisation (ISI) regime in Brazil. The establishment of an industrial site at the heart of the Brazilian Amazon region derived from a government policy that sought not only to stimulate economic development in that area, but also to integrate it into Brazil's economy. One of the mechanisms for implementing such a policy was the creation of the Superintendence of the Industrial Pole of Manaus in 1967. This organisational structure, under the Ministry of Development, Industry and Foreign Trade, has been operating as a regulatory body and regional development agency (for industrial, commercial, agribusiness, and tourism sectors). Its main activities include: management of the tax-incentive regime (in place since 1967), attracting national and foreign investors, stimulating the local human resource basis and the facilitation of interaction between firms and local innovation system supporting organisations, fostering investments in physical infrastructure, stimulation of exports and the dissemination of industrial development across and inside the Brazilian Amazonian states (Suframa, 2006).

Specifically, the tax-incentive framework is one of key pillars of this government policy and involves two major levels of incentives. At the federal level: (i) import tax: reduction up to 80% over inputs to be manufactured; (ii) exemption of tax on manufactured goods; (iii) reduction of 75% of income tax, based on net profit; and (iv) exemption of social integration tax (Pis) and of social security tax (Cofins) for transactions carried out within Manaus. At the state level: compensation between 55% and 100% of value added tax. In 2004 such fiscal regime of Manaus was extended up to 2023. Additionally, at the municipal level there is exemption of urban state tax and of garbage collection services and also exemption of license fees for firms that generate more than 500 direct jobs (Suframa, 2005). Such tax-incentive framework is, however, more a generic type of incentive policy – to attract firms – rather than any type of performance-conditioned incentive (e.g. innovative performance) (see, for instance, Teubal, 2000;Wade, 2000).

A consultation into a Suframa's database showed that the Industrial Pole of Manaus consisted, up to end of 2006, of 17 different industrial sectors (nearly 450 firms, 128 of which are of foreign capital). The total annual revenue evolved from US$ 5.9 billion, in 1991, to nearly US$ 20 billion, in 2006, or by 8.5% annually on average. In 1999, 43,095 people were directly employed in firms in the Industrial Pole of Manaus; by December 2006, there were around 90,000 (Suframa, 2005).

Additionally, by end of the fieldwork for this research there were in Manaus a set of innovation system supporting organisations, such as 20 universities (public and private), eight research centres and institutes, one business incubator and four technical training centres, liaison and coordination organisations (e.g. the Secretary for S&T of the state of Amazonas, the Industrial Pole of Manaus Technological Centre), and research funding organisations. Many of these universities and research centres/institutes emerged and/or were strengthened from the early 1990s as a result of the implementation of the information and communication (ICT) policy – known as the 'Brazilian ICT Law' (Law 8248, 1991). On the basis such law, ICT-related firms in Manaus are stimulated to invest five per cent of their revenue in research and development (R&D) activities on a local basis. Additionally, ICT-related firms operating in Southern and Southern Brazil have to allocate part of their five per cent for investments in universities and research institutes located in the North, North-east, Mid-west regions of the country. Differently from the existing tax-incentive framework within the Industrial Pole of Manaus (commented earlier in this sections), the incentives under the ICT Law are more related to a performance-conditioned incentive, focused on R&D activities.

4. Research methods

This paper has been structured to address the issues of firm-level capability development in association with some of the key sources of such capabilities (knowledge links) in the light of government policy. Such issues are examined in the context of a sample of 46 firms in the Industrial Pole of Manaus and 29 supporting organisation of the Manaus' innovation system (see Table 3).

Table 3. Sample composition: firms and innovation system supporting organisations

Sampled organisations	*Functions and numbers of the sampled organisations*						Total
	Research institutes	Government universities	Funding, liaison, and normative organisations	Training centres	Consulting firms	Business incubators	
	6	3	12	4	2	2	29
Types of firms	*TNC-subsidiaries*					*Local firms*	Total
	USA	Europe [(a)]	Japan	South Korea	Sub-total TNCs		
Electro-electronics (EE)	6	3	3	1	13	5	18
Motorcycles and bicycles (MCB)	1	0	2	0	3	6	9
Key suppliers	2	0	6	0	8	11	19
Total sampled firms	9	3	11	1	24	22	46
Total sampled organisations							75

Note: (a) Finland, Germany, and France.

The key criterion for selecting these firms was based on purposeful sampling in order to choose information-rich cases from which one can learn a great deal about issues of central importance to the research purpose (Patton, 1990). The firms were selected on the basis of consultation of databases from the Brazilian Association of the Electro-Electronics Industry (Abinee), the Brazilian Association of Bicycle and Motorcycles Industries (Abraciclo), Suframa's and the Secretariat of the Science and Technology of the State of Amazonas.

The EE and the MCB industries are the two leading sectors in Manaus, accounting for around 36 and 23 per cent of the Pole's total revenue, respectively, in 2006. During the 1992-2004 period, the revenue (in USD billion) of the EE sector in Manaus grew by 8.6 per cent annually on average; the MCB's by 17.5 per cent. In 2006 the sampled EE firms held about 90 per cent of the production volume and market-share in Brazil, whereas the sampled MCB firms held 100 per cent of both production and market-share. They represented around 80 per cent of the total EE firms and 100 per cent of the active MCB firms in Manaus.

The implementation of this data-gathering strategy produced a rich amount of first-hand qualitative and quantitative empirical evidence. Rather than reduce all the qualitative data to quantitative observations, the strategy here sought to combine both types of evidence in order to enrich the empirical analysis. Used thus, the qualitative evidence, presented in the form of narratives, helps both strengthen the arguments and establish causal relationships (Dougherty, 2002), as well as interpret the quantitative evidence (Figueiredo, 2001).

The fieldwork for this research was carried out from March 2002 to December 2004 with a follow-up in early-2006. The primary data was gathered mainly in Manaus and to some extent in São Paulo (where plants and corporate offices of some of the firms are located). Individual and collective in-depth interviews, direct-site observations, and casual meetings involving directors, managers, engineers, technicians, crew supervisors, and some operators were used in the data gathering process. Additionally, there were interviews with directors, researchers, professors, managers, engineers, and technicians of supporting organisations of the local innovation system in Manaus. Such interviews were followed by direct-site observations in both pilot study and main fieldwork. Other sources also included leaders of industry associations (Manaus and São Paulo) and key academicians in Manaus. There were interviews with some of Suframa's top officials coupled with a systematic search in the agency's vast database.

5. Key findings and discussions

5.1 Changes in industrial policy regimes in Brazil

Main changes in industrial policy regimes in Brazil are briefly outlined in Table 4. The consumer electronics industry in Brazil emerged during the late-1960s under the ISI policy and a heavily protected market. It expanded during the 1970s as a result of economic growth and the expansion of durables consumption in Brazil.

Table 4. Main changes in industrial policy regimes in Brazil

	Periods	Key features of policy regimes		Some implications for policy in the Manaus Industrial Pole
Protectionist and inward-looking policy regime	Late-1950s: set up protection policy	Introduction of a protectionist regime on the basis of *ad valorem* tariffs. Federal government had discretionary power to control the level of imports and activated the *Lei do Similar Nacional* (the Law of Similars), under which a product could only be imported if it could be proved that a similar product was not produced in Brazil.		
	1960s – early-1980s: intensification of the protectionist policy	Expansion of non-tariffs barriers based on: (i) a list of 1,300 products that were not permitted to be imported (the so-called 'C Annex'); (ii) all firms were required to submit their annual plan for imports in advance to federal government; (iii) access to fiscal subsidies and subsidized credit was conditioned by domestic content of an investment project. Imports were made under special regimes granted to exporters (drawback) or were non-competitive capital and intermediate goods.	→	Start-up of manufacturing activities
	1985-1988: The 'New Industrial Policy'	New policies sought (formally) to reduce redundancy in the tariff structure, to lower manufacturing tariffs from 90 to 43%, and to reduce the number of special regimes. However, as shown in Kume (1989) and Hay (2001), in practice, such measures had little impact: (i) tariffs plus taxes continued to lead to redundant protection in virtually all sectors; non-tariffs barriers and the 'the Law of Similars' remained in place. Indeed, such reforms were not as radical as formally announced, particularly due to the strong opposition from local producer interest groups (see Kume, 1989).	→	Setting up of policy based on minimum nationalization degree of components of products manufactured in Manaus Setting up of maximum limits of annual imports
Outward-looking policy regime	Early 1990s: consolidation of the trade liberalisation policy followed by macro-economic stabilization from the mid-1990s.	Reforms introduced by the Collor administration from March 1990 represented a **major break** with the protectionist regime of the past (Hay, 2001). Such reforms covered three areas: (i) the C Annex (the list of 1,300 products with prohibition on import was eliminated; (ii) all relevant non-tariff barriers were removed; (iii) introduction of a four-year tariff reduction program to bring all tariffs into the range of 0 to 40%. Reductions were carried out as scheduled until October 1992, when the federal government decided to advance the timetable by six months. In 1994 the 'Real Plan' was introduced in order to achieve macro-economic stabilization. This policy has to date proved successful in taming inflation and stabilizing the Brazilian economy. Inception of the new ICT Law implementation (1991)..	→	The policy of 'minimum national content of product components was replaced by the 'basic (or minimum) production process policy'; Strong concern with export performance All firms were forced to obtain the ISO 9000 certification. Emergence and/or strengthening of research institutes and university labs stimulated and supported by the resources originated from the ICT Law implementation.

Sources: Elaborated on the basis of Kume (1989), Moreira & Correa (1998), Hay (2001), and Armijo (2005).

As was the case in most developing countries, Brazil began to receive a considerable number of TNC-subsidiaries from the 1960s. By the late-1960s there were about 20 companies in Brazil producing TV sets, of which three were foreign. The implementation of the 'market reserve' policy (Law 7.232, 1984) stimulated the emergence of a local electronics components industry in Brazil. By the late-1980s there were nearly 23 semiconductor firms in Brazil, with some located in Manaus. However, the trade liberalizing measures adopted by the federal government in March 1990 led to a drastic reduction in the historically high import tariffs in Brazil (from 114 per cent in 1966 to 21 per cent in 1993). Additionally, there was the enactment of the new ICT Law (Law 8.248, 1991 – mentioned earlier) that began to provide tax incentives for final products rather than components.

Consequently, 20 out of the 23 semiconductor firms that were in operation during the 1980s, disappeared from the industry in the early-1990s. Revenue from semiconductors production in Brazil dropped from US$200 millions in 1989 to US$54 millions by 1998 (see Brazilian Ministry of Science and Technology – MCT, 2002), reflecting a 'lack of coordination and of supplementary industrial and technology policies, and even a divergence between them, in relation to the electronics complex' (MCT, 2002: 24).

The systematic reductions in import tariffs during the mid 1990s (from 115.9% in 1987 to 16.7% in 1997) also favoured the emergence of new MCB firms in Brazil. For example, four new motorcycle firms started activities in Manaus – on a SKD (semi- knocked down) and later on a CKD (complete knocked down) basis. A third large bicycle firm was set up in 1996 in Manaus. As indicated during field interviews and by Suframa's database, within two years this third firm had outperformed the two existing and traditional Brazilian bicycle firms both in terms of technological activities and market-share. By 2002 it had become the largest bicycle producer in Latin America.

From 1991 there was a gradual and steady reduction of trade barriers combined with a set of actions to de-regulate and open up the Brazilian economy to foreign competition (Baer, 1994). In parallel, the National Privatisation Program sought to sell off large state-owned companies. Privatisation was deemed as part of a long-term program based on the liberalization process leading to novel conditions within which firms began to operate (Suzigan & Villela, 1997).

An industrial policy was implemented to prepare the economy for world competition. In April 1990, the Industrial and Foreign Trade Policy (PICE), consisting of several programmes, was implemented to stimulate the development of industrial capability. These programmes also involved fiscal and credit incentives. The Brazilian Program of Quality and Productivity (PBQP) consisted of: (i) sub-programme to disseminate new management and production organization techniques (e.g. TQC/M, JIT) in manufacturing industries; and (ii) the creation and upgrading of institutions and organisations for manufacturing quality control (e.g. a law for consumers' rights (which until then was absent in Brazil) and the strengthening of metrology-related organisations).[5]

5.2 Evidence of technological capability in the sampled firms

5.2.1 Types and levels of technological capability

Table 5 summarises the number of sampled firms (both local and TNC-subsidiaries) that had attained specific types and levels of technological capabilities by the time of our fieldwork. The evidence in Table 5 shows that all 46 sampled firms had mastered basic operations across

[5] Consumers' rights and responsibilities in Brazil were first regulated by Law 8,078 (1990). Such law also created the Department of Consumer's Protection and Defence (1990) under the Ministry of Justice.

the three technological functions. In general, there were no significant differences between local and TNC-subsidiaries in terms of existing levels of capabilities, except at the level of specific functions (for details, see Figueiredo, 2007).

Table 5. Number of sampled firms that have reached specific levels of technological capability [(a)]

Types and levels of technological capabilities by sector	Electro-electronics (EE)			Motorcycle and bicycles (MCB)			Key suppliers		
	Process and production organization	Product–centred	Equipment-related activities	Process and production organisation	Product–centred	Equipment-related activities	Process and production organisation	Product–centred	Equipment-related activities
Mastery of basic operations Level 1	18 (100%)	18 (100%)	18 (100%)	9 (100%)	9 (100%)	9 (100%)	19 (100%)	19 (100%)	19 (100%)
Mastery of basic operations Level 2	18 (100%)	18 (100%)	18 (100%)	9 (100%)	8 (89%)	4 (44%)	18 (95%)	18 (95%)	15 (79%)
Basic innovation Level 3	18 (100%)	13 (72%)	9 (50%)	8 (89%)	3 (33%)	3 (33%)	14 (74%)	9 (47%)	5 (26%)
Intermediate innovation Level 4	14 (78%)	3 (17%)	2 (11%)	3 (33%)	1 (11%)	2 (22%)	7 (37%)	1 (5%)	1 (5%)
High-intermediate innovation Level 5	11 (61%)	0 (not attained)	0 (not attained)	2 (22%)	1 (11%)	1 (11%)	1 (5%)	0 (not attained)	0 (not attained)
Advanced innovation Level 6	0 (not attained)	0 (not attained)	0 (not attained)	1* (11%)	1* (11%)	1* (11%)	0 (not attained)	0 (not attained)	0 (not attained)

S*ource:* Derived from the empirical study; *Note:* (a) Situation during the fieldwork period.

As one of the leading organisations charged with implementing the federal industrial policy of 1990, Suframa took steps to force every firm to obtain the ISO 9002 certification no later than 1992. This measure forced firms to review their capabilities, particularly for process and production organization activities. Our findings suggest that such a compulsory measure contributed to pushing several of the sampled firms into the building of Level 2 capabilities, especially for process and production organization and product-centred activities by 1993.

Interviews and observations within Suframa indicated that, over these past 15 years, this government body has been transforming itself from a mere fiscal regulator into an active development agency for the Amazon region. Suframa can thus be seen as part of a long-term government initiative to develop this area of Brazil and should not be ignored as part of the institutional (and macro-organizational) framework for industrial development in the area.

As far as rates of capability development were concerned, such measurement involves the historical period that goes from each firm's start-up time up in Manaus to the end of fieldwork in 2005. Table 6 provides a glimpse of inter-sector, inter-firm, and intra-firm differences and commonalities in terms of rates (speed) and time-scales to move through different levels of capabilities (for details, see Figueiredo, 2007).

Table 6. Mean speed to move through different technological levels in the sampled firms

Movements through technological capability levels	**Technological functions**								
	Process and production organization			**Product-centred**			**Equipment-related**		
	EE	MCB	Suppliers	EE	MCB	Suppliers	EE	MCB	Suppliers
L1➔ L2	10.3	10.9	14.8	11.9	12.9	18	7.1	7.8	8.8
L2 ➔L3	3.8	5.8	2.8	2.4	5.3	4.3	2.5	2.6	3.8
L3 ➔ L4	2.1	2.7	2.5	2.2	1	2.7	1.5	2	2
L4 ➔L5	1.6	Not attained	Not attained	1.3	1	1.3	1	Not attained	Not attained
L5 ➔L6	Not attained	Not attained	Not attained	1.5	Not attained	1.3	Not attained	Not attained	Not attained

Source: Derived from the empirical study;
Note: See Appendices C and D for statistical results.

5.2.2 Local firm-level decision-making and control

This section addresses the issue of whether firms in Manaus have developed reasonable levels of local management's capability for decision-making and control (see Table 7). This indicator was observed only within the EE and MCB samples. The capability for independent local management, i.e., without foreign management, has been frequently raised by other studies (see, for instance, Ariffin & Bell, 1999; Ariffin, 2000). In this paper, sampled TNC subsidiaries were found to have varied levels of local management control over procurement, pricing, product development, recruitment, training, distribution and marketing.

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

Level of local decision-making and control	Examples of activities to indicate local decision-making and control	Electro-electronics (EE) firms			Motorcycles and bicycles (MCB) firms			Totals
		TNCs subsidiaries	Local independent firms	Sub-total	: TNCs	Local independent firms	Sub-total	
Limited or passive role & capability (Level 1)	Recruitment of production workers, human resource training. Supervisory of assembly and routine operations.	None	None	None	1	4	5	5 (19%)
Basic active role and capability (Level 2)	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.	6	1	7	None	1	1	8 (30%)
Intermediate active role and capability (Level 3)	100 per cent 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.	5	4	9	1	1	2	11 (41%)
Advance active role and capability (Level 4)	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.	2	None	2	1	None	1	3 (11%)
Totals		13	5	18	3	6	9	27 (100%)

Source: Derived from the empirical study.

At the lowest level (Level 1), local staff hold very few managerial positions, limited to those related to recruitment and training of operating staff, and supervision of routine production operations. Among the 27 sampled EE and MCB firms, five were observed to be at this level, among them one TNC subsidiary and four domestic firms (see Table 7). On the other hand, 11 firms (41 per cent) that were found at Level 3 and three firms (11per cent) observed at Level 4 have demonstrated active and advanced role and capability for local decision-making and control.

Additionally, the results in Table 8 indicate a strong association ($p<0.05$) between levels of capability for local decision-making and control and technological capability levels, particularly for process and production organisation, for the EE sample, and equipment-related activities, for the MCB sample. In other words, EE and MCB firms that have deeper levels of technological capabilities exhibit higher levels of local decision-making and control, respectively, for process and production organisation and equipment-related activities.

Table 8. Kruskal Wallis test for local decision-making and control

	Level of local decision-making and control					
	EE fims			MCB firms		
	Proc	Prod	Equip	Proc	Prod	Equip
Chi-square	6.679	3.580	4.388	6.836	6.836	7.920
Df	2	2	2	3	3	3
Asymptotic Significance	0.036*	0.167	0.111	0.077	0.077	0.048*

Note: (*) Association significant at the 0.05 level

Such findings suggest that local management within TNC-subsidiaries with deep levels of local decision-making and control are not just passively implementing a set of strategies and directions from TNC parents. Instead, the local management bids and competes with other subsidiaries world-wide in a process of negotiation with TNC parent to influence TNC corporate strategies to upgrade product complexity, investment levels, and increase technological and deepening of technological activity levels in Manaus. These *negotiated* processes virtuously use the deepening levels of local technological capabilities of subsidiaries as leverage in competing for greater mandates and more significant roles within the global TNCs. This also seems to suggest that the attainment of this capability level, especially for the sampled TNC-subsidiaries, means that firms at such innovative capability level were able to engage in an internationally integrated network of innovation, in line with Cantwell & Mudambi (2005).

For instance, by early 2004 Honda Manaus won a global bid to receive a major investment to expand its site thus becoming one of world's largest (if not the largest) motorcycle site within the group. The Manaus site competed against other Honda sites like Thailand and Mexico. Fieldwork interviews within Honda in Manaus, revealed that this subsidiary draws on its innovative capability levels and competitive performance to bid and compete against other subsidiaries within the group to engage in more sophisticated technological activities. Another example is the gradual building of its product design and development centre in Manaus and the mould maintenance unit. As revealed by interviews in the company, the idea is to evolve into a unit for mould design. On the basis of this, Honda Manaus seeks to supply the Americas from Manaus thus combining a local with a global market strategy.

5.3 Inter-firm knowledge links as sources of firms' capabilities

5.3.1 Knowledge flows through subsidiary-parent firm links

As shown in Table 9, EE firms have moved into the building of innovative links (LI-links) with their parent firms instead of being confined to MP-links and LP-Links. During the 2003-5 period all valid sampled firms had built up LI-links related at least one type of technological capability. Additionally, by 2003-5 all valid sampled firms had built up LI-links with their parent firms in Brazil. Unfortunately, the results in Table 9 did not allow us to establish causality between capability levels and these learning links. The reason is that LI-links were present in the great majority of the valid sampled firms and it was not possible to identify differences. Nonetheless, the qualitative evidence suggests that firms that have developed these LI-links were those firms that have built up the deepest levels of technological capabilities.

Table 9. Number of firms that have developed specific types of inter-firm technological links: subsidiary-parent types of link

	Links with parent or sister companies – global (for TNC subsidiaries)							Links with parent company – Brazil (for local firms)						
	Electro-electronics firms			MCB firms				Electro-electronics firms[a]			MCB firms[c]			
	2001	2002	2003-5	1986-89	1990-95	1996-2000	2001-5	2001	2002	2003-5	1986-89[b]	1990-95	1996-2000	2001-2005
MP-Link	13 100%	13 100%	13 100%	3 100%	3 100%	3 100%	3 100%	15 100%	15 100%	15 100%	5 100%	8 100%	7 100%	7 100%
LP-Link	13 100%	13 100%	13 100%	2 67%	3 100%	3 100%	3 100%	15 100%	15 100%	15 100%	5 100%	8 100%	7 100%	7 100%
LI-Link	10 77%	13 100%	13 100%	0	1 33%	2 66%	2 66%	14 93%	14 93%	15 100%	0	1 12%	1 11%	3 37%
I-Link	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: Derived from the empirical study

Notes: (a) Not applicable for two firms (Thomson and Nokia) and data not available for one firm (Tyco Electronics);
(b) Four firms had not entered the industry at that time;
(c) Not applicable for Harley-Davidson from 1986 to 2005 (the subsidiary has not 'parent' firm in Brazil, but report directly to Milwaukee). Not applicable for Honda from 1996. The subsidiary closed down its local headquarter in São Paulo and concentrated all its motorcycle activities in Manaus.

As far as the MCB sample was concerned, Table 9 shows that by 2003-4 all valid sampled firms had engaged in learning for production links (LP-links) with their parent firms either globally or in Brazil. Indeed, these two firms have developed the deepest capability levels among the sample. However, only two firms (Honda and Yamaha) have engaged in learning for innovation links (LI-links) with their global parent firms, whereas three firms (37 per cent) have built up innovative links with their parent firms in Brazil. Again, the results in Table 9 did not permit us to claim a statistical association between these learning links and capability levels. One exception is the strong association between capability for equipment related activities and learning links in the MCB sample ($p<0.05$) (see results in Table 10).

Table 10. Kruskal Wallis test for inter-firm technological links and capability levels

	Links with parent or sister firms – world TNC groups						**Links with parent firm in Brazil[a]**			**Links with local supplier – Manaus (from the perspective of EE and MCB firms)**						**Links between suppliers and users in Manaus (from the perspective of suppliers)**		
	Electro-electronics firms			MCB firms			MCB firms			Electro-electronics firms			MCB firms			Suppliers		
	Proc	Prod	Equip	Proc	Prod	Equip	Proc	Prod	Equip	Proc	Prod	Equip	Proc	Prod	Equip	Proc	Prod	Equip
Chi-square	1.944	1.500	1.231	3.000	3.000	3.000	4.950	5.185	6.622	13.114	5.447	7.622	5.737	5.737	7.840	5.347	8.200	2.808
Df	1	1	1	3	3	3	2	2	2	2	2	2	3	3	3	2	2	2
Asymptotic Significance	0.163	0.221	0.267	0.392	0.392	0.392	0.084	0.075	0.036*	0.001**	0.066	0.022*	0.125	0.125	0.049*	0.069	0.017*	0.246

Note: (*) Association significant at the 0.05 level; (**) Association significant at the 0.01 level;
[(a)] In the electro-electronics sample there is only one incidence of the LI category. Thus, it was not possible to run the test.

5.3.2 Building capabilities via local producers and customers/users links

5.3.2.1 From the perspective of EE and MCB producer firms

As shown in Table 11, EE and MCB valid sampled firms have progressively moved from marketing-production links to learning links (LP and LI-links) over time. By 2003-5, ten EE firms (55 per cent) had built up LI-links with their local suppliers. The results in Table 10 shows that these links have been significant ($p<0.01$ and $p<0.05$, respectively) to the building of technological capabilities, particularly for process and production organisation and equipment related activities. In other words, EE have been drawing on some of their local suppliers as a source of knowledge to improve their capability levels, especially in these two functions.

Table 11. Number of firms that have developed specific types of inter-firm technological links with local suppliers (from the perspective of the EE and MCB producer firms)

	Links with local suppliers						
	Electro-electronics (EE) firms			MCB firms			
	2001	2002	2003-5	**1986-89[a]**	**1990-95[b]**	**1996-2000**	**2001-2003-5**
No link	2 11%	1 5%	1 5%	1 20%	3 43%	4 44%	4 44%
MP-Link	16 89%	17 94%	17 94%	4 80%	4 57%	5 55%	5 55%
LP-Link	16 89%	17 94%	17 94%	2 40%	3 43%	5 55%	4 44%
LI-Link	10 55%	10 55%	10 55%	0	2 28%	2 22%	2 22%
I-Link	0	0	0	0	0	0	0

Source: Derived from the empirical study.

Notes: (a) Four firms had not entered the industry at that time; (b) Two firms had not entered the industry at that time.

As for the MCB sample, two firms (22%) have consistently built up and sustained innovative learning links (LI-links) over the 1986-2005 period. Indeed, the results in Table 10 even show a strong association ($p<0.05$) between capability levels for equipment-related activities and innovative inter-firm technological learning links. In other words, the firms that have developed Levels 5 and 6 innovative capabilities for equipment activities have also built up and sustained their LI-links with local suppliers.

It should be noted, however, that one EE firm (5%) and four MCB firms (44%) have not established any type of link with suppliers. Although this evidence is not representative for the EE sample, it draws attention to the case of MCB sector. While in the EE sample innovative capability levels were more spread across the sample, in the MCB sample these capabilities are more concentrated in two firms (Yamaha and, especially, Honda). However, Honda is the only sampled firm that has reached Level 6 capability for the three technological functions – though in an incomplete manner (see Table 5). Additionally, since the late-1980s, Honda has fully concentrated its Brazilian two-wheel activities in Manaus and has systematically attracted a chain of suppliers has stimulated the emergence and sustainability of local suppliers.

5.3.2.2 From the perspective of supplier firms (suppliers – customers)

The evidence in Table 12 shows a steady progression of the number of firms towards the building of innovative learning links.

Table 12. Number of firms that have developed specific types of inter-firm technological links: from the perspective of suppliers firms

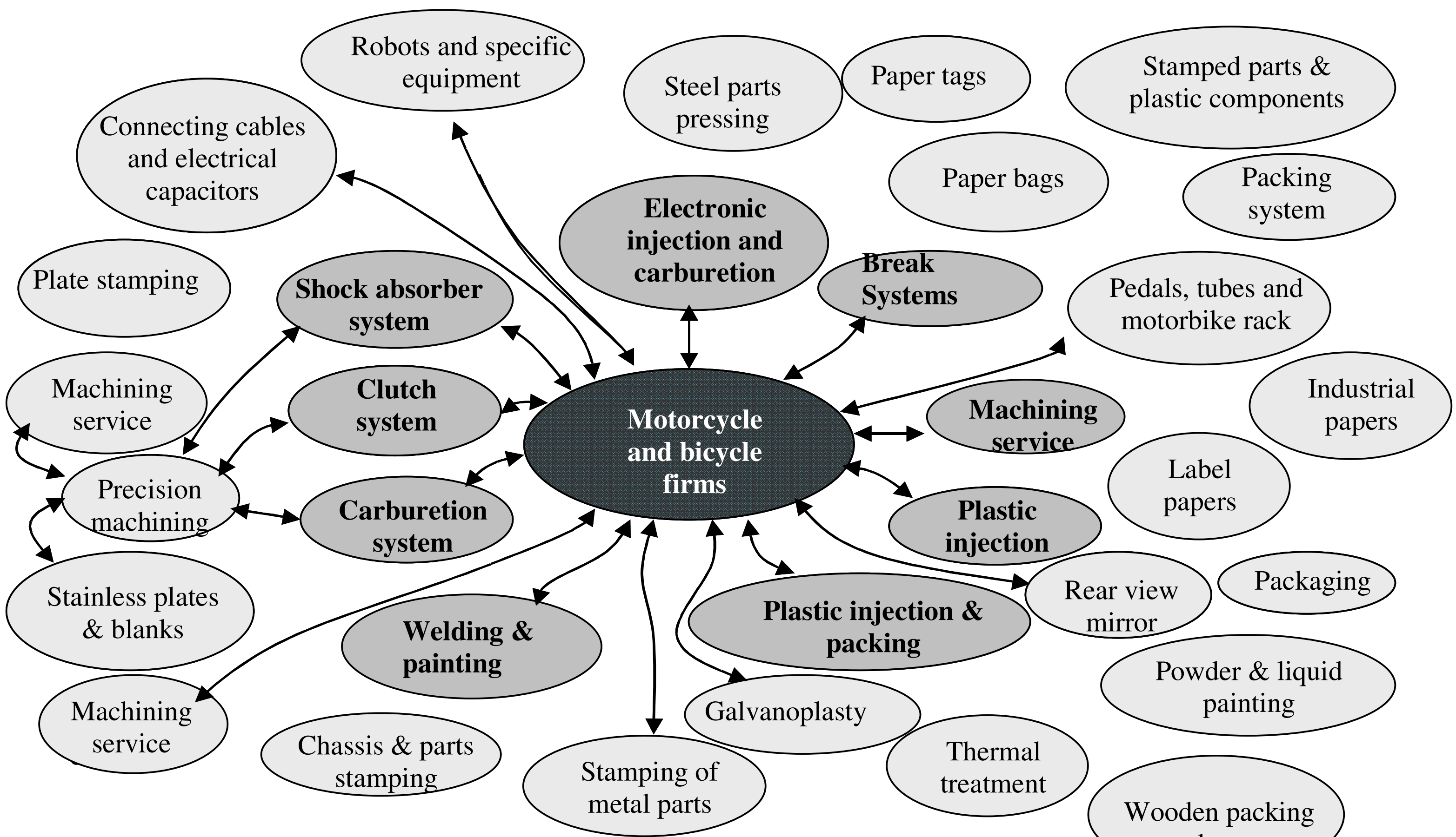
Types of links	Links with local users/customers			
	1986-89	1990-95	1996-2000	2001-2003-5
MP-Link	5 100%	7 100%	15 100%	19 100%
LP-Link	5 100%	6 85%	13 86%	17 89%
LI-Link	0	2 28%	6 40%	13 68%
I-Link	0	0	0	0

Source: Derived from the empirical study

While during the 1986-89 period there were only five firms involved in LP-links, by the 2003-2005 period 17 firms (89% of the current sample) had developed links based on learning for production (LP-links). While during the late-1980s none of the sampled firms had developed links based on learning for innovation (LI-links), during the 2003-5 period 13 firms (68% of the current sample) had built up these LI links with their users/customers in the EE and MCB sectors. Indeed, the empirical evidence suggests that supplier firms have benefited from these learning links to build up their innovative capabilities. For instance, the results in Table 12 shows a strong association between technological learning links and the building of capabilities for products ($p<0.05$). In other words, supplier firms that have built up innovative learning links (LI-links) with their users are those that have developed deeper levels of technological capabilities.

In sum, differently from the EE sample, in which innovative technological capabilities were more diffused among the sampled firms, in the MCB sample the highest levels of innovative capabilities were indeed concentrated in two TNC-subsidiaries, mainly in Honda, as mentioned earlier in this section. Indeed, this firm's strategy of suppliers development, implemented over the past decade, has contributed to the emergence of a chain of dedicated suppliers in the Industrial Pole of Manaus. The configuration of such 'supply chain' and some of the knowledge flows are roughly represented in Figure 1.

Figure 1. Representation of the MCB 'supply chain' and some knowledge flows in the Industrial Pole of Manaus



Key: → = knowledge flows for innovative technological capability development

Source: Derived from the empirical study

While most of first-tier suppliers are TNC-subsidiaries, this study identified local second- and third-tier suppliers (from Manaus) of important activities (e.g. metal bath, robot maintenance). Such firms have emerged out the initiative of entrepreneurs (most of them engineers). These suppliers are either TNC subsidiaries or local firms of 12 employees led by entrepreneur engineers. Such local firms have, on average, 12 to 25 employees and are run by entrepreneur technicians and/or engineers who moved into Manaus, from other regions of Brazil, during the late-1980s and early-1990s, to start up their own businesses.

Thus, the innovative technological activities of companies such as Honda Manaus is no longer confined within its boundaries, but have been spilling over to local small and medium-sized firms. This also suggests that, the presence of a local network of suppliers would imply that a large TNC subsidiary like Honda has created a kind of 'regional root'. As Lall (2003) pointed out, this is one of the ways of taking advantage of the presence of TNCs in order to foster local industrial development.

5.4 Inter-organisational knowledge links: firms and innovation system supporting organisations

This section examines evidence relative to the links set up between the sampled firms and the sampled innovation system supporting organisations. Table 13 presents evidence of the nature of knowledge-centred links between firms and supporting organisations of the innovation system (or 'who interacts with who'), on the basis of their types (informal, human resources and formal), while Table 14 presents descriptive statistics, but in terms of specific types of links established between supporting organisations of the innovation systems and the sectors examined here. Table 15, in turn, presents evidence of the main results emerging from such linkages, from the perspective of the sampled firms. The evidence indicates that:

Table 13. Types of links established between firms and supporting organizations of the innovation system

Innovation system organizations/types of links	Electro-electronics			MCB firms			Key supplier firms		
	Informal	HR	Formal	Informal	HR	Formal	Informal	HR	Formal
Research institutes	34 (54.8%)	6 (20.0%)	17 (56.7%)	6 (22.2%)	5 (16.7%)	NF	3 (23.0%)	3 (8.1%)	1 (16.7%)
Consulting firms	2 (3.2%)	1 (3.3%)	9 (30.0%)	2 (7.4%)	NF	NF	NF	2 (5.4%)	3 (50.0%)
Universities	23 (37.1%)	12 (40.0%)	4 (13.3%)	14 (51.9%)	11 (36.7%)	NF	7 (53.8%)	6 (16.2%)	NF
Support organizations	NF	1 (3.3%)	NF	NF	1 (3.3%)	NF	NF	2 (5.4%)	NF
Training centres	1 (1.6%)	10 (33.3%)	NF	4 (14.8%)	12 (40.0%)	NF	1 (7.7%)	22 (59.5%)	2 (33.3%)
Incubators	NF	NF	NF	NF	NF	NF	NF	NF	NF
Other	2 (3.2%)	NF	NF	1 (3.7%)	1 (3.3%)	NF	2 (15.4%)	2 (5.4%)	NF
Total	62 (100.0%)	30 (100.0%)	30 (100.0%)	27 (100.0%)	30 (100.0%)	0 (0%)	13 (100.0%)	37 (100.0%)	6 (100.0%)

Source: Derived from the research; NF = not found

Table 14. Descriptive statistics of specific types of links between firms and innovation system supporting organisations

Industries	Types of links	Number of firms	Links					
			Mean	Median	Maximun	Minimum	Std. Deviation	Total links
Electro-electronics	Overall links	18	6.8	6.5	15	1	4.3	122
	Informal links	14	4.4	4	10	1	2.3	62
	Human resources	12	2.5	2	6	1	1.7	30
	Formal links	12	2.5	2	5	1	1.6	30
MCB	Overall links	9	6.3	7	15	1	4.6	57
	Informal links	6	4.5	4	7	3	1.6	27
	Human resources	9	3.5	4	8	1	2.3	30
	Formal links	-	-	-	-	-	-	-
Suppliers	Overall links	18	3.1	2	10	1	2.9	56
	Informal links	6	2.2	1.5	4	1	1.5	13
	Human resources	18	2.1	1	6	1	1.6	37
	Formal links	4	1.5	1	3	1	1	6

Source: Derived from the research

Table 15. Results from links established between firms and supporting organizations of the innovation system

Types of results	EE firms			MCB firms			Key suppliers		
Results/Links	Informal	HR	Formal	Informal	HR	Formal	Informal	HR	Formal
Verbal advices	6.5	NF	16.7	NF	NF	NF	NF	NF	33.3
Provision of information	17.7	13.3	30.0	14.8	10.0	NF	15.4	2.7	66.7
Reports	22.6	NF	36.7	3.7	3.3	NF	7.7	2.7	66.7
Specific programmes	53.2	63.3	53.3	51.9	60.0	NF	30.8	64.9	50.0
Technical and organisational improvements	15.0	22.5	NF	26.2	25.1	NF	49.7	29.7	16.7
Design	11.3	NF	10.0	NF	NF	NF	NF	NF	NF
Prototypes	4.8	NF	3.3	3.7	3.3	NF	NF	NF	NF
Patents	NF	NF	NF	NF	NF	NF	NF	NF	NF
Other	1.1	1.8	NF	3.4	1.6	NF	4.1	2.7	NF

Source: Derived from the research; Keys: HR = Human resources links; NF = not found

(i) Informal links present, on average, higher levels of incidence in relation to formal and human resources links;

(ii) Except for formal links, E&E and MCB firms have set up a similar number of links with the supporting organisations. However, the dispersion is higher for the E&E sector than for MCB sector, mainly when informal links are considered. This means that MCB firms show a more homogeneous behaviour in relation to the establishment of links, particularly informal links, in comparison to E&E firms. Supplier firms, on the other hand, showed a more limited interaction with innovation system supporting organisations;

(iii) As shown in Table 15, the results generating from such linkages are more concentrated on the provision of technical information, reports, and the implementation of specific programmes. Evidence from interviews revealed that such specific programmes were related to shared-problem solving, automation projects, introduction of organisational innovations, co-development relative to product-centred and process and production organisation improvement activities, and technical training for dedicated teams (intermediate to high-innovative capabilities).

Table 16 presents results a statistical test relative to the relationship between firms' maximum capability levels, in terms of sector and specific technological functions, and the number of linkages established with the supporting organisations of the local innovation system. The evidence indicates that:

Table 16. Spearman rank correlations between firm-level capabilities and the number of links established by firms

Types of firms	Types of capability					
	Process and production organisation	n	Product-centred	n	Equipment, tool & die, metal stamping, plastic injection	n
Electro-electronics	-0.092	18	0.017	18	0.059	18
MCB	0.838**	9	0.773**	9	0.773**	9
Suppliers	0.639**	18	0.689**	18	0.479*	18

*Correlation is significant at the 0.05 level (two tailed).
**Correlation is significant at the 0.01 level (two tailed).
Source: Derived from the research

(i) For the E&E sector, and considering the three technological functions – process and product organisation, product-centred and equipment-related – the results indicate no association between the level of technological capability achieved in each function and the number of links established with supporting organisations;

(ii) For the MCB sector and, again considering the same three technological functions, there is a positive significant association ($p<0.01$) between capability for all three technological functions and the number of links established with supporting organisations;

(iii) Supplier firms present an intermediate position in relation to E&E and MCB sectors: there is positive and significant association for process and production organisation ($p<0.01$) and for product-centred capabilities ($p<0.05$)

Finally, Table 17 presents results a statistical test relative to the association between firms' maximum capability levels, by type of firms and technological functions, and the nature of linkages (informal, human resource-based, and formal) established with the supporting organisations of the local innovation system. The evidence indicates that:

Table 17. Spearman rank correlations between firm level capability and types of links established by the firms

	Sectors and Types of capability											
	Electro-electronics				MCB				Key suppliers			
Types of links	Process and production organisation	Product-centred	Equipment, tool & die	n	Process and production organisation	Product-centred	Equipment, tool & die	n	Process and production organisation	Product-centred	Equipment, tool & die	**n**
Informal links	-0.193	-0.121	-0.148	14	0.813*	0.874*	0.985**	6	-0.365	-0.424	-0.317	6
Human resources	0.123	0.219	0.507*	12	0.680*	0.570	0.454	9	0.647**	0.613**	0.601**	18
Formal links	-0.370	-0.444	-0.525*	12	-	-	-	-	0.816[a]	0.816[a]	0.816[a]	4

*Correlation is significant at the 0.05 level (two tailed).
**Correlation is significant at the 0.01 level (two tailed).
a The amount of firms with formal links (4) was not enough for the correlation be considered

(i) *E&E firms:* the only positive and significant association was found for the equipment-related capability in terms of human resources and formal links ($p<0.05$);

(ii) *MCB firms:* there was a strong correlation between the number of informal links set up and capability levels for all three technological functions, especially for equipment-related capability: the higher the level of capability achieved, the higher the number of links established). Contrary to the EE sector, the MCB sample showed a strong association between the number informal links and, to some extent, human resources-based links and maximum capability levels;

(iii) *Supplier firms:* there was a positive and significant association between human resource-based links and suppliers firms' maximum capability levels ($p<0.01$). Qualitative evidence from fieldwork indicates that some suppliers developed links with local technical education centres and universities in order to upgrade the skills of their personnel as part of their efforts to improve their capabilities to supply both EE and, especially, MCB firms.

6. Conclusions and policy implications

This paper sought to address the issues of firm-level capability development in association with some of the key sources of such capabilities (knowledge links) in the light of government policy. These issues were examined based on extensive fieldwork that involved the gathering of first-hand intra-organisational evidence from a sample of 75 organizations (46 firms and 29 supporting organizations of the innovation system), all located in the context of the Industrial Pole of Manaus, Northern Brazil.

In general, the study found a diversity of firms' capability types and levels and a variety of sources to build up and/or sustain those firm-level capabilities, specifically, two different types of knowledge linkages: (i) inter-firm knowledge linkages (links established between sampled Brazilian and TNC-subsidiaries in Manaus with their parent firms elsewhere and links between local producers and local suppliers); and (ii) inter-organisational knowledge links (links set up between the sampled firms and local innovation system supporting organisations (e.g. universities, research institutes, consulting firms, training centres). On the one hand, such findings indicate that the sampled firms (local firms and TNC-subsidiaries) are actively seeking to build up their own knowledge basis in order to carry out their innovative technological activities. On the other, the evidence also shows the emergence of a set of supporting organisations of the local innovation system on which firms can draw as a source of knowledge for their capability building efforts. Additionally, this evidence shows the consolidation of relatively small, but active local innovation system in a less developed area of Brazil, in which this kind of arrangement is expected not to exist.

Such results show that the patterns of firm-level capability development and the emergence of different kinds of knowledge links (either within firms' groups or with the supporting organisations of the local innovation system) exhibited positive responses to the structural reforms of the 1990s. However, this does not mean that such positive responses were a mere consequence of trade openness. Neither does this study support the idea that liberalization *per se* is an effective measure for industrial development (or a Washington Consensus-type of argument).

It is important to recognize the presence of a purposeful government policy that has been in place over the past 40 years (see Section 3) in addition to the policy initiatives from the 1990s (e.g. the ICT Law and others) – (see Sections 3 and 5). In the absence of such government policies, all these firms and some innovation system supporting organisations would probably not even be there in the first place. Conversely, this study does not suggest a mere return to the ISI strategy. Instead, the evidence here suggests that a combination of government policy, foreign competition, firms' capability building efforts, and the emergence of a local innovation systems supporting organisations have been proving essential for capability development in some of the sampled firms.

Consequently, policy for accelerating industrial technological capability development in a developing area such as the one examined here would involve not only macro-level measures and incentives (e.g. economic stabilization, export stimuli, tax-based arrangements) and competition, but, very importantly, measures that facilitate intra-firm capability building efforts. This could involve, for instance, the design of incentives for progressive firm-level capability building coupled with continuous and constructive assessment exercises. Additionally, local development agencies could also provide firms with access to foresight exercises (technological and market), identification of sources of knowledge (local and non-local) for diverse technical and organisational activities, and also dissemination of successful experience, particularly those of local suppliers. Additionally, the existing general fiscal incentive policy in Manaus could be more focused on intra-firm-level innovative performance followed by systematic assessment mechanisms. In parallel, the implementation of the ICT Law in Manaus should also be accompanied by mechanisms of continuous assessment in order to contribute to improving the local innovation system.

Despite these findings and the recommendations that emerge from them, this study has some weaknesses. Some of them were mentioned in Section 1. The inclusion of more sectors and different kinds of firms and an inter-country comparison would undoubtedly increase the robustness of the analysis. The scope of the present study did not extend to the issues of firms' entry and exit over a long period. This is a dimension that could prove beneficial for a better macro and meso-level perspective on the implications of policy changes for industry in the region. Indeed, it would have been useful to explain in more detail why firms that exited the industry could not cope with the foreign competition.

Nevertheless, this paper also contributes to drawing our attention to the fact that, after nearly 20 years of those structural reforms, it is about time that future studies moved beyond the polarized perspectives on the implications of the structural reforms of the 1990s for industrial development into a nuanced alternative view based on the analyses of key factors that are likely to influence the acceleration of firms' innovative capability development in the context of late-industrialization under global competition. Thus combination of industry-level aggregated analyses and intra-firm studies from a dynamic perspective would be valuable for clarifying our understating of how latecomer firms and industries could strive beyond their current innovative capability levels. This may prove a crucial step in efforts at generating concrete, more realistic and feasible recommendations for decision-makers concerned with innovation related issues in the context of late industrialization.

Acknowledgements
I feel honoured for having benefited from Sanjaya Lall's insightful and encouraging comments on part of the research underpinning this paper. I dedicate this paper to his memory. I have also benefited from the positive and challenging comments on an earlier version of this paper during the Meeting of Experts on 'FDI, Technology and Competitiveness – A conference convened in honour of Sanjaya Lall', especially from Richard Nelson, Jorge Katz, Frances Stewart, Raphael Kaplinsky, Carlo Pietrobelli, Carl Dahlman, Francisco Sercovich, and Rajah Rasiah. Also, I am grateful to Martin Bell for continuously inspiring me to improve my research in this field. Very special thanks go to all companies that have participated in the fieldwork for this research and to Marcela Cohen for her invaluable research assistance. I thank the Brazilian Government Ministry of Development, Industry and Foreign Trade for sponsoring this research. The usual disclaimers apply.

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Appendix A. A framework for technological capabilities in the electro-electronics industry (producer firms and suppliers)

Types and Levels of Capability	Process and production organization	Product-centred	Equipment Tool & die, metal stamping, plastic moulding
Routine technological capabilities: capabilities for the use of given technologies			
Mastery of basic operations Level 1	SKD (semi-knocked down): parts assembly, only final assembly. Assemble kits: dissemble and re-assemble kits. PPC: production planning and control. Organizing basic process flow. Visual testing only.	Routine QC to maintain basic standards: in-coming, final product inspection, out-going inspection.	Basic maintenance but equipment suppliers stationed at plant.
Mastery of basic operations Level 2	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.	Routine maintenance of tools and equipment. Total Preventative Maintenance (TPM). Total Productive Maintenance. Replication of unchanging equipment components.
Innovative technological capabilities: capabilities to generate and manage technical change			
Basic innovation Level 3	Set-up of Process, Production or Industrial Engineering Dept/s. Improved layout & debugging to optimize production. ISO 9002, statistical process control (SPC), quality control circles (QCC), total quality management (TQM), 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.	Repair & trouble-shoot equip problems. Copying and simple adaptation of existing designs and/or specifications. Set-up Equipment Design, Tool, Die & Mould Development centers. Engineering/fairly precision metal and plastic parts.
Intermediate innovation Level 4	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. ISO 9001, Software development, systems engineering.	Develop automated equipment. Equipment Design Centre upgraded to separate firm. Mould & die design. High precision tooling, progressive metal stamping, plastic injection moulding.

High-intermediate Innovation Level 5	Radical innovation in organization. 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 Centers or world product mandates. Providing design services to TNC Group or customers.	R&D for specifications and designs of new high precision tools, complex automated equipment or production systems. Patents. Set-up of recognized training institutes in precision tool & die, or precision plastic molding with universities.
Advanced innovation Level 6	Process and software development to produce & test high yield, miniaturized 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. R&D into more uniform crystal growth, improved magnetic orientation, advanced materials.	Fast time-to-design cutting-edge and hi-precision equipment to produce latest or cutting-edge products and components Is among regional or global leaders of CNC complex equipment, high precision tooling, stamping, die & mould, prototype models.

Source: Drawn from Ariffin (2000) and Ariffin & Figueiredo (2004).

Appendix B. A framework for technological capability accumulation in the latecomer motorcycle and bicycle industry (producer firms and suppliers)

Types and levels of capabilities	Process and production organisation	Product-centred	Equipment –related activities
Routine technological capabilities: capabilities for the use of given technologies			
Mastery of basic operations Level 1	Lay-out of acquired technology across the plant. Routine production co-ordination across plant. Semi-knocked down (SKD) production – simple assembly of components. Absorbing plant designed capacity. Basic PPC and visual tests.	Production of limited variety of models. Production focused on national market. Products based on SKD production. Routine QC for incoming material and final products.	Basic maintenance assisted by equipment suppliers located at the plant. Basic mastering of maintenance of tooling. Routine replacement of equipment components.
Mastery of basic operations Level 2	Basic co-ordination of process flows and adjustments to the production line. Complete knocked down (CKD) production. Efficiency improvement on the basis of accumulated experience from existing activities. Routine testing. Achieving certification for routine process QC (e.g. ISO 9002, QS 9000).	Increase in the variety of models for national markets. Products derived from CKD production. Replicating given product specification from the group. In-line QC. Product quality for export markets. Routine product QC awarded international certification (e.g. ISO 9002, QS 9000).	Maintenance of jigs and of devices of assembly/testing. Participation in installations and performance test. Total preventive maintenance (TPM). Organization of the Maintenance Dept/Division.
Innovative technological capabilities: capabilities to generate and manage technical change			
Basic innovation Level 3	Building of department of process, production and industrial engineering. Layout improvement, problem solutions, minor and intermittent adaptations in process, de-bottlenecking, and 'capacity-stretching'. Systematic studies of new process control systems – SPC, TQC/M, ZD, MRP, Kanban/JIT.	Creating of local product specifications. Diversification of product line. Building of Product engineering Dept. Cosmetic and mechanical design. Minor adaptation to product design to meet local market conditions and/or demand.	Maintenance of casting, machining, welding and dying equipment. Total productive maintenance. Replication of simple equipment components. Adaptation of equipment components to local inputs and to characteristics of production process organization. Adjustment to tools, devices and moulds. Manufacturing of jigs. Automated precision machining.
Intermediate innovation Level 4	Processes of automation for innovation (e.g. production process system control, automation to speed up process flow), flexible and multi-skilled production. Production ramp-up. Failure analysis (e.g. FMEA). Production process improvement for the development and use of local suppliers (for 40-50% of whole product components).	Systematic improvements upon given product specifications. Licensing new product technology. Own/local production of product components. Development and local suppliers (for 40-50% of whole product components). Early design for manufacturing (DFM).	Autonomy to carry out periodic revision of equipment and machinery without technical assistance. Basic and detailed process engineering. Own complete maintenance. Precision mechanics for tooling, stamping by plastic injection. Moulds maintenance.

High-intermediate Innovation Level 5	Quality assurance Programs with suppliers. Plant and business re-organization. Integrating automated process control and PPC Application of CATIA, and/or Pro-engineering. Logistics systems for JIT delivery. ISO 14.000 certification. Develop. local suppliers – supply chain (for 50-80% of whole product components).	Product development certification (e.g. ISO 9001). Early engagement in product design, prototyping and local development of products. Own launch of new products. Award of product in international markets. Building of product development group. Speed up of prototyping.	Own manufacturing of equipment components. Design of pressing and molding. Development engineering of components for new products. Software development for equipment and production lines automation. Design and development of sensors for equipment and product tests. Early engagement in moulds design.
Advanced innovation Level 6	Engagement in new production Integrated automated operations systems with corporate control systems. Engaging in process innovation based on research and engineering. Strengthening and management of whole supply chain aiming for total local supply. World-class production. New process design and development via E and R&D.	Building of dedicated product design and development unit. Design of components. Complex JIT systems with suppliers. Leadership within the group in terms of product R&D. Local project and development of all products. Launching of internationally innovative products (new concepts). Product patenting.	Complex and high-precision mechanical and electronics engineering. Moulds design, development, application and maintenance. Maintenance assistance to other firms in the group. High-precision mechanics. R, D & E for new specifications of design and high-precision tooling, automated equipment, production system, and moulds. Patents. Centre for molding and high-precision mechanical engineering strongly linked with university research.

Sources: Adapted from Lall (1992), Bell & Pavitt (1995), Ariffin (2000) and Figueiredo (2001);

Notes: E = engineering; JIT = just-in- time; PPC = production planning and control; QC = quality control; TQC/M = total quality control and management; ZD = zero defect.

Appendix C. Rates (speed) to move through different technological capability levels in the EE sampled firms

Movement (or lack of) through different capability levels	Technological capabilities types and accumulation speeds		
	Process and production organization	Product-centered	Equipment-related activities
Level 1 ➔ Level 2	Mean =10.3, Med =7.3, SD=9, Min=0, Max=23, n=18	Mean =10.9, Med =9.5, SD=8.6, Min=1, Max=23, n=18	Mean =14.8, Med =12.5, SD=9.4, Min=2, Max=28, n=18
Level 1 ➔ Level 3	Mean =14.1, Med =11.3, SD=10.1, Min=2.5, Max=28, n=18	Mean =17.5, Med =16, SD=9.8, Min=3, Max=30, n=13	Mean =16.4, Med =16, SD=9.2, Min=4, Max=29, n=8
Level 1 ➔ Level 4	Mean =15.7, Med =14, SD=9.9, Min=5, Max=29.5, n=15	Mean =26, Med =29, SD=6.1, Min=19, Max=30, n=3	Mean =24.5, Med =24.5, SD=9.2, Min=18, Max=31, n=2
Level 1 ➔ Level 5	Mean =19, Med =17, SD=9.6, Min=7, Max=31, n=11	-	-
Level 2 ➔ Level 3	Mean =3.8, Med =3.8, SD=1.6, Min=1.5, Max=7, n=18	Mean =5.8, Med =7, SD=2, Min=2, Max=8, n=13	Mean =2.8, Med =2, SD=1.4, Min=2, Max=5, n=8
Level 2 ➔ Level 4	Mean =5.7, Med =5, SD=1.8, Min=3, Max=10.5, n=15	Mean =7.7, Med =8, SD=0.6, Min=7, Max=8, n=3	Mean =7.5, Med =7.5, SD=0.7, Min=7, Max=8, n=2
Level 2 ➔ Level 5	Mean =7.8, Med =7, SD=1.3, Min=7, Max=11.5, n=11	-	-
Level 3 ➔ Level 4	Mean =2.1, Med =2, SD=0.9, Min=1, Max=5, n=15	Mean =2.7, Med =3, SD=0.6, Min=2, Max=3, n=3	Mean =2.5, Med =2.5, SD=0.7, Min=2, Max=3, n=2
Level 3 ➔ Level 5	Mean =3.9, Med =4.5, SD=1.1, Min=2, Max=6, n=11	-	-
Level 4 ➔ Level 5	Mean =1.6, Med =1.5, SD=0.4, Min=1, Max=2, n=11	-	-

Source: Derived from the empirical study

Appendix D. Rates (speed) to move through different technological capability levels in the MCB sampled firms

Movement (or lack of) through different capability levels	Technological capability types and accumulation speeds		
	Process and production organization	Product-centered	Equipment-related activities
Firms that have remained stuck at Level 1	-	n=1 5 years	Mean =10.5, Med =10, , SD=5, Min=5, Max=17, n=4
Level 1 ➔ Level 2	Mean =11.9, Med =8, SD=8.8, Min=1, Max=26, n=9	Mean =12.9, Med =11.5, SD=7.7, Min=4, Max=24, n=8	Mean =18, Med =19, SD=11, Min=4, Max=30, n=5
Level 1➔ Level 3	Mean =14.4, Med =12, SD=9.3, Min=5, Max=29, n=6	Mean =16.3, Med =18, SD=8.6, Min=7, Max=24, n=3	Mean =15.3, Med =15, SD=8.5, Min=7, Max=24, n=3
Level 1 ➔ Level 4	Mean =16, Med =18, SD=9.2, Min=6, Max=24, n=3	n=1 Speed = 25	Mean =22.2, Med =22.2, SD=4.5, Min=19, Max=25.3, n=2
Level 1 ➔ Level 5	Mean =16.3, Med =16.3, SD=13.1, Min=7, Max=25.5, n=2	n=1 Speed = 26	n=1 Speed = 26.7
Level 1 ➔ Level 6	n=1 Speed = 27	-	n=1 Speed = 28
Level 2 ➔ Level 3	Mean =2.4, Med =2, SD=1.4, Min=1, Max=5, n=6	Mean =5.3, Med =5, SD=2.5, Min=3, Max=8, n=3	Mean =4.3, Med =5, SD=1.2, Min=3, Max=5, n=3
Level 2 ➔ Level 4	Mean =5, Med =5, SD=3, Min=2, Max=8, n=3	n=1 Speed = 6	Mean =7.7, Med =7.7, SD=1.9, Min=6.3, Max=9, n=2
Level 2 ➔ Level 5	Mean =4.8, Med =4.8, SD=2.5, Min=3, Max=6.5, n=2	n=1 Speed = 7	n=1 Speed = 7.7
Level 2 ➔ Level 6	n=1 Speed = 8	-	n=1 Speed = 9
Level 3 ➔ Level 4	Mean =2.2, Med =2.5, SD=1, Min=1, Max=3, n=3	n=1 Speed = 1	Mean =2.7, Med =2.7, SD=1.9, Min=1.3, Max=4, n=2
Level 3 ➔ Level 5	Mean =3, Med =3, SD=1.4, Min=2, Max=4, n=2	n=1 Speed = 2	n=1 Speed = 2.7
Level 3 ➔ Level 6	n=1 Speed = 5.5	-	n=1 Speed = 4
Level 4 ➔ Level 5	Mean =1.3, Med =1.3, SD=0.4, Min=1, Max=1.5, n=2	n=1 Speed = 1	n=1 Speed = 1.3

Level 4 ➔ Level 6	n=1 Speed = 3	-	n=1 Speed = 2.7
Level 5 ➔ Level 6	n=1 Speed = 1.5	-	n=1 Speed = 1.3

Source: Derived from the empirical study

Appendix E. Rates (speed) to move through different technological capability levels in the supplier sampled firms

Movement (or lack of) through different capability levels	Technological capability types and accumulation speeds		
	Process and production organization	Product-centered	Equipment-related activities
Firms that have remained stuck at Level 1	n=1, Years = 9	n=1, Years = 9	Mean =7.8, Med =7.5, Mode=x, SD=5.1, Min=2, Max=14, n=4
Level 1➔ Level 2	Mean =7.1, Med =5.5, SD=5.5, Min=1, Max=17, n=18	Mean =7.8, Med =5.8, SD=5.7, Min=1, Max=17, n=18	Mean =8.8, Med =7, SD=6.1, Min=1, Max=19, n=15
Level 1 ➔ Level 3	Mean =9.9, Med =7.3, SD=6.9, Min=2, Max=22, n=14	Mean =9, Med =7, SD=7.3, Min=2, Max=22, n=9	Mean =11, Med =6, SD=9.7, Min=2, Max=22, n=5
Level 1 ➔ Level 4	Mean =11.7, Med =8, SD=8.2, Min=4, Max=23, n=6	n=1, Speed = 24	n=1, Speed = 24
Level 1 ➔ Level 5	n=1, Speed = 24	-	-
Level 2 ➔ Level 3	Mean =2.5, Med =2, SD=1.3, Min=1, Max=5, n=14	Mean =2.6, Med =2, SD=2.1, Min=1, Max=7, n=9	Mean =3.8, Med =3, SD=2.3, Min=1, Max=7, n=5
Level 2 ➔ Level 4	Mean =4.2, Med =3, Mode=3, SD=1.8, Min=3, Max=7, n=6	n=1, Speed = 7	n=1, Speed = 7
Level 2 ➔ Level 5	n=1, Speed = 7	-	-
Level 3 ➔ Level 4	Mean =1.5, Med =1.5, SD=0.3, Min=1, Max=2, n=6	n=1, Speed = 2	n=1, Speed = 2
Level 3 ➔ Level 5	n=1, Speed = 2	-	-
Level 4 ➔ Level 5	n=1, Speed = 1	-	-

Source: Derived from the empirical study