Industrial policy changes and firm-level technological capability development: evidence from Brazil

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Abstract
Much has been written about the impacts of the policy changes of the 1990s on industrial performance, particularly in Latin America. Most of the studies are based on aggregated analyses that argue for or against such reforms in the policy regime. This study offers an alternative view to this debate based on a longitudinal empirical scrutiny of technological capability development in 46 local and foreign firms from three sectors in Northern Brazil. There were inter-sector and inter-firm variations in terms of the manner and rate of capability development for specific technical functions. Overall, the patterns of firm-level capability development exhibited a positive response to the structural reforms, but such responses were not a mere consequence of trade openness. A combination of government policy, foreign competition, and intra-firm capability building efforts have proved essential for speeding up capability development in some of the sampled firms. Therefore policies for accelerating industrial technological capability development in a developing area such as the one examined here would involve not only macro-level incentives and competition, but, very importantly, measures that facilitate intra-firm capability building efforts.

Key words: Industrial policy regimes; firm-level technological capability, Southern Latin America, Northern Brazil.

JEL code: O31, O32, O14.

1. INTRODUCTION
Following the changes of the early 1990s into an outward-looking policy regime in several developing countries, particularly in Latin America, there have been different perspectives on the effects of such reforms on industrial progress. From a Washington-consensus standpoint, it has been advocated that liberalization per se would lead to industrial development, economic growth, and competitiveness (World Bank, 1993). However, there is a level of scepticism about the effects of trade openness on industrial growth (e.g. Rodríguez & Rodrik, 2000), with some arguing that the structural reforms of the 1990s have had a negative impact on the existing industrial technological capabilities in Southern Latin America (e.g. Cimoli & Katz, 2003 among others). Nevertheless, while it may 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 liberalization is also likely to prevent developing...
countries such as those in Latin America from speeding up their technological development (Westphal, 2002; Lall, 2003, 2006).

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. As a result, 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. This paper takes up that task. The paper does not seek to engage in the polemics of an inward-looking versus outward-looking policy regime. It instead focuses on patterns 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. By doing so, the paper seeks to offer an alternative view of the implications of such structural reforms for firm-level technology accumulation.

This paper is organized as follows. Following this introduction, Section 2 reviews the study background. The analytical framework underlying this study is presented in Section 3. The empirical setting in which the study was developed is briefly outlined in Section 4, whereas the research methods are described in Section 5. The empirical analysis, discussions, and a summary of key findings are presented in Section 6. Finally, Section 7 presents the paper conclusions and policy implications.

2. STUDY BACKGROUND

Research into the implications of policy regimes for technology-led industrialization in developing countries gained considerable attention from the 1940s through the works of R. Prebisch and H. Singer leading to the emergence of the ‘dependency theory’. However, from the early 1970s the ‘dependency’ perspective was challenged by a set of pioneering empirical studies that adopted a dynamic perspective on technology in firms Latin America and Asia: they left aside the static question of choice from a given set of techniques (Stewart & James, 1982).

They looked instead at the process by which firms built up – or failed to build up – their innovative technological capabilities (see Cooper & Sercovich, 1971; Katz, 1976, Dahlman and Fonseca, 1978; Cooper, 1980; Bell et al., 1982; Lall, 1987 among others). Other studies examined the nature of policy interventions and some of their differing implications for firm-level technological capability building (see, for instance, Cooper, 1980; Maxwell, 1981; Castaño & Katz, 1986; Dahlman et al., 1987; Teitel, 1992). However, over the past few years empirical studies addressing the implications of the structural reforms of the 1990s for industrial development have tended to adopt a relatively polarized view of this issue, particularly in Latin America. They can be organized in at least two broad categories.

The first, although from diverse standpoints and at differing degrees, have suggested positive implications of those changes for industrial performance (e.g. technical efficiency, productivity gains and resource allocation in manufacturing sectors) 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 Bolivia (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. ‘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 industrialization (see Lall, 1990, 1992; Bell & Pavitt, 1993; Ariffin, 2000).

A second category of studies argues that the reforms of the 1990s did not have any positive impact on the pattern of industrial specialization in Latin American countries (see Katz, 2000; Reinhardt & Peres, 2000; Ocampo, 2001). As argued in Cimoli & Katz (2003) and Katz (2004) changes in the institutional environment that left behind 40 years of ‘state-led’ development strategies have pushed Latin American economies into a ‘low development trap’ and to the destruction of deeply rooted forms of production organization and technological capabilities. In a similar vein, drawing on a country-level aggregated analysis, Narula (2002: 32) also points out that, ‘the switch from ISI [import substitution industrialization] to NEM [new economic model] in Latin America does not bode well for the prospects for industrial development.’ They do however agree on the overall macro-economic improvement brought on by these changes.

Because such studies are based on aggregated analyses that derived from government-related database, they do not capture nuances and variability in patterns of technological capability development within regions, sectors, and firms. Additionally, because of the use of the aggregated approach such studies tend to over generalize the ‘Latin American experience’, thus, missing out the larger intra-continent industrial diversity. Sharing a similar view, but focusing on Brazil, some studies have suggested that the structural reforms have pushed firms into the adoption of ‘defensive strategies’, marked by a weakened capacity to expand and to carry out innovative activities. They also hold a negative view of the contribution of subsidiaries of trans-national corporations (TNCs) to the local industrial development (see Ferraz et al., 1996; Haguenauer et al., 1998; Coutinho, 1997; Rocha & Kupfer, 2002), even suggesting that TNCs have been eroding local existing innovative technological capabilities (see Aman & Baer, 1998; Cassiolato et al., 2001).

Such generalizations have been contradicted in Costa & Queiroz (2002) and, to some extent, in Kannebley Jr. et al. (2005). However, based on an Oslo Manual-type and a one-point-in-time design, drawn on large-scale samples of sectors and firms derived from industrial censuses, these two studies missed out on the process of capability building from an intra-sector and firm-level perspective. Some single-case studies on the other hand suggest a more varied and positive picture of TNC’s technological activities in Brazil over time, especially during and after the 1990s (e.g. Consoni & Quadros, 2006; Tacla & Figueiredo, 2006). Although they reveal important intricacies of firm-level capability building processes, they also do not allow us to identify inter-firm and inter-sector similarities and/or differences in terms of capability development.

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’.

The present paper seeks to offer a contribution in this direction. It focuses on the pattern of firm-level technological capability accumulation in the context of changes in policy regimes in Brazil during the 1970s-2005 period. These issues are examined on a relatively small sample of 46 firms – local firms and TNC-subsidiaries drawn from three sectors: electronics (hereafter EE); motorcycles and bicycles (hereafter MCB) and suppliers. The firms are located in one of the developing and least researched areas of Brazil: the Industrial Pole of Manaus. Some industry observers in Brazil hold the view that such an industrial area is merely a set of ‘screw-driver’ plants, although these are evidence-free generalizations (see, for instance, Forbes Brasil, 2000; Fleury & Fleury, 2004).

One of the main limitations of the present paper is that it does not cover key factors influencing firms’ capability development such as intra-firm learning processes (Bell, 1984; Kim, 1997; Dutrènit, 2000; Figueiredo, 2001; Tacla & Figueiredo, 2006), inter-organizational knowledge links (Ariffin & Bell, 1999; Ariffin, 2000), and the interaction with innovation system supporting organizations (Lall, 1992; Albu & Bell, 1999). Firms’ technological accumulation may also be influenced by other intra-organizational factors like leadership, values and beliefs (Figueiredo, 2001; Vera-Cruz, 2006). These factors are however outside the scope of this paper. Additional weaknesses of the study underlying this paper are outlined in Section 7.

3. ANALYTICAL FRAMEWORK

3.1 An ‘assimilation’ perspective on industrial development

Industrial development in late-industrializing countries and regions is normally examined from different perspectives such as ‘accumulation’ and ‘assimilation’ theories. The former stresses the role of high investments rates in physical systems and human capital in achieving development. Differently, 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). From this perspective, the firm is viewed as a dynamic organization and as a repository of productive knowledge that distinguishes it even from similar firms in the same line of business (Winter, 1988). This evolutionary perspective 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).

As a result, there is a ‘permanent existence of asymmetries between firms in terms of their process technologies and quality of output. That is, firms can be generally ranked as “better” or “worse” according to their distance from the technological frontier’ (Dosi, 1988:1155-6).
Differences across industrial sectors in terms of innovative efforts are expected to occur as a result of differing demands, sources of innovation and appropriability mechanisms (Pavitt, 1984; Dosi, 1988; Malerba, 2005). In addition, ‘firms in a sector have some commonalities and, at the same time, are heterogeneous (Malerba, 2005: 385), although there also are intra-firm differences in terms of capability building for different technological functions (see Dutrènit, 2000; Arrifin, 2000; Figueiredo, 2001).

These perspectives are in line with the purpose of this paper. It takes the view that the accumulation 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 behavior 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 behavior (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).

3.2 Measuring firm-level technological capability in this study

3.2.1 An alternative framework for measuring firm-level technological capability

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 organizational systems (Bell & Pavitt, 1993). Their accumulation proceeds from simpler to more difficult categories and ‘there is a basic core of functions in each major category that have to be internalized by the firm to ensure successful commercial operation.....That basic core must grow over time as the firm undertakes more complex tasks’ (Lall, 1994:267). Such a framework is useful for describing the paths of technological capability accumulation followed by latecomer firms.

This paper thus focuses its assessment and analysis on a wider range of firms’ innovative capabilities rather than on R&D and patenting capabilities or on production capabilities alone. Technological capability is examined here on the basis of a Sanjaya Lall type of taxonomy. Adapted from Lall (1990, 1992) and Bell & Pavitt (1995), such typology makes a relatively fine disaggregation of different levels and types of technological capability.

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Specifically, the framework distinguishes between ‘routine’ production capability and ‘innovative’ technological capability. ‘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 organizational arrangements. ‘Innovative’ technological capability is defined as the capability to create, change or improve products, processes and production organization, or equipment. It may be described as change-generating capability, consisting of technology-changing skills, knowledge, experiences and organizational arrangements.

To examine technological capability development in this study, such taxonomy has been tailored for electro-electronics firms and suppliers (see Appendix A) and bicycle and motorcycle firms and suppliers (Appendix B). The columns set out the technological capabilities by function; the rows, by level 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.  

3.2.2 Rate (or speed) of firm-level technological capability development

In addition to the examination of the manner of capability development, this framework also permits the identification of time-scale differences between firms and functional areas in terms of capability accumulation. Rate (or speed) of capability development is defined here as the time (number of years) a firm takes to reach a capability level for specific technological functions (Ariffin, 2000; Figueiredo, 2001; Tacla & Figueiredo, 2006). Specifically, as in Ariffin (2000), the rate to reach a higher technological capability level from a lower level is measured in terms of the year in which a firm started activities on a particular level to the year it started activities on the next (in the context of the framework in Appendices A-B). The time needed to reach specific capability, say, from Level 1 (basic operations) to Level 3 (basic innovation) and beyond is based on events and activities that demonstrate that a firm has started to carry out activities related to that particular capability level.

As pointed out in Bell (2006), during the past thirty years or so, the late-industrializing community of scholars has failed to address the issue of the time-scale involved in the process of capability accumulation. Although there are a few exceptions (e.g. Katz, 1987; Ariffin, 2000; Figueiredo, 2001; Tacla & Figueiredo, 2006), more empirical evidence of the time-scale involved in firm-level capability building is badly needed.

4. THE EMPIRICAL SETTING

The Industrial Pole of Manaus started up in 1967 under the ISI regime in Brazil. The establishment of an industrial site at the heart of the Amazon region derived from a government policy that sought not only to stimulate economic development in that area, but also to integrate it into the Brazilian 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 organizational structure, under the Ministry of Development, Industry and Foreign

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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).
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 base and the facilitation of interaction between firms and local innovation system supporting organizations, fostering investments in physical infrastructure, stimulation of exports and the dissemination of industrial development across and inside the Brazilian Amazonian states (Suframa, 2005).

The tax-incentive framework is one of key pillars of this government policy and involves two 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) income tax: reduction of 75% based on net profit; and (iv) social integration tax (Pis) and social security tax (Cofins): exempt for transactions carried out within Manaus. At the state level: value added tax – compensation between 55% and 100%. In 2004 the fiscal regime of Manaus was extended up to the year 2023 (Suframa, 2005).

On the basis of the Suframa database, the Industrial Pole of Manaus consists of 17 different industrial sectors (nearly 400 firms, 128 of which are of foreign capital). The total annual revenue evolved from US$ 5.9 billion, in 1991, to US$ 18.9 billion, in 2005, or by 8.5% annually on average. From 1998 to 2005 annual revenue grew by 9.6% annually on average. In 1999, 43,095 people were directly employed in firms in the Industrial Pole of Manaus; by December 2005, there were around 66,000 (Suframa, 2005).

5. RESEARCH METHODS

This paper has been structured to address one question: to what extent has the pattern of firm-level capability development changed relative to the industrial policy reforms of the early 1990s? Such question is examined in the context of a sample of 46 firms in the Industrial Pole of Manaus (see Table 1).

Table 1. Sample composition

<table>
<thead>
<tr>
<th>Types of sampled firms</th>
<th>TNC-subsidiaries (a)</th>
<th>Local firms (b)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>USA</td>
<td>Europe (c)</td>
<td>Japan</td>
</tr>
<tr>
<td>Electro-electronics (EE)</td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Motorcycles and bicycles (MCC)</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Key suppliers</td>
<td>2</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>3</td>
<td>11</td>
</tr>
</tbody>
</table>

Notes: (a) Only foreign firms; (b) Firms from Manaus or from South-eastern and Southern Brazil; (c) 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) and Suframa’s.

The EE and the MCB industries are the two leading sectors in Manaus, accounting for 36% and 20.5% of the Pole’s total revenue, respectively, in 2005. During the 1992-2004 period, the revenue (in USD billion) of the EE sector in Manaus grew by 8.6% annually on average; the MCB’s by 17.5%. In 2005 the sampled EE firms held about 90% of the production volume and market-share in Brazil, whereas the sampled MCB firms held 100% of both production and market-share. They represented around 80% of the total EE firms and 100% 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 late-2005. 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. 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.

6. EMPIRICAL ANALYSIS AND DISCUSSIONS

6.1 Changes in industrial policy regimes in Brazil

Main changes in industrial policy regimes in Brazil are briefly outlined in Table 2. 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>
<thead>
<tr>
<th>Periods</th>
<th>Key features of policy regime</th>
<th>Some implications for policy in the Manaus Industrial Pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protectionist and late-1950s: set up protection policy</td>
<td>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 <em>Lei do Similar Nacional</em> (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.</td>
<td></td>
</tr>
<tr>
<td>1960s – early-1980s: intensification of the protectionist policy</td>
<td>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 subsidised 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.</td>
<td>Start-up of manufacturing activities</td>
</tr>
<tr>
<td>1985-1988: The ‘New Industrial Policy’</td>
<td>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).</td>
<td>Setting up of policy based on minimum nationalization degree of components of products manufactured in Manaus</td>
</tr>
<tr>
<td>Early 1990s: consolidation of the trade liberalisation policy followed by macro-economic stabilization from the mid-1990s.</td>
<td>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.</td>
<td>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.</td>
</tr>
</tbody>
</table>

*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% in 1966 to 21% in 1993). Additionally, there was the enactment of the new information and communication technology (ICT) law (Law 8.248, 1991) that provided 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).

In the late-1980s, Brazil was left behind in the electronics industry, especially in the production of semiconductors and other components, while countries like Malaysia, South Korea, and Taiwan, that had adopted a different institutional framework characterized by a convergence between government and industry actions during the 1980s, forged ahead. This was despite of the fact that these countries had started from a relatively lower stage of development in electronics (MCT, 2002). This interpretation is in line with in-depth studies of the electronics industry development in East Asia (see Hobday, 1995; Ariffin & Bell, 1999; Mathews, 1999; Ariffin, 2000). As a result, the components segment of the electro-electronics industry in Brazil was weakened.4

The bicycle industry started up in Brazil during the early 1900s, by an entrepreneur Italian immigrant, while the motorcycle production began in the mid 1970s by Japanese large companies. In 1975, at the peak of the ISI policy, the Brazilian government prohibited motorcycles importation. This measure forced firms like Honda and Yamaha to review their strategies and to initiate manufacturing activities in Brazil. While Honda decided to concentrate its operations in Manaus, Yamaha’s operations were wholly set up in São Paulo until 1985, when it transferred part of its activities to Manaus.

The Honda unit in Manaus represents one of the highest private investments in that area. In 1977, Honda made 27,000 out of the 34,000 motorcycles produced in Brazil. Reflecting its strong production capability, as indicated by the evidence in this study, this number evolved to 3,600 motorcycles per day in 2006 (100cc to 600cc) accounting for 79% of the market share in Brazil. From the mid 1990s, nearly 80% of motorcycle components were acquired in Manaus due to the presence of a chain of nearly 25 suppliers. Some of these suppliers were particularly attracted by Honda and Yamaha during the 1990s. On the one hand, these supplier firms (both foreign and local) came to Manaus attracted in part by the tax regime and

4 The electro-electronics industry in Brazil involves: industrial automation, industrial equipment, computer-related goods, electricity generation and transmission, electric installation materials, telecommunications, domestic appliances, and components. In 2005 this industrial sector accounted for 4.8% of Brazil’s GDP.
in part by the macro-economic stability and growth of the Brazilian economy (following the Real Plan, see Table 2). This in turn, resulted in the impressive growth of the MCB industry in Brazil (see Section 5). On the other, during the 1990s, as a result of Japan’s economic recession, large firms were encouraged by the Japanese government to intensify the off-shoring of their manufacturing activities, particularly to developing countries.5

The systematic reductions in import tariffs during the mid 1990s (from 115.9% in 1987 to 16.7% in 1997) also favored 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. Evidence of key technological activities in these bicycle firms’ is presented as follows.

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 Privatization Program sought to sell off large state-owned companies. Privatization 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 programs, was implemented to stimulate the development of industrial capability. These programs also involved fiscal and credit incentives. The Brazilian Program of Quality and Productivity (PBQP) consisted of: (i) sub-program 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 organizations for manufacturing quality control (e.g. a law for consumers’ rights (which until then was absent in Brazil) and the strengthening of metrology-related organizations).6

Indeed, the policy changes of the early 1990s swept away several firms that were not able to cope with the international competition brought on by such changes. For instance, as mentioned earlier, all those 20 electronic components firms that were closed down did so in the aftermath of the opening up of the Brazilian economy. Another firm that was hit hard by the changes was Sharp Brazil, one the successful electronics firms in operation during the 1970s and 1980s in the country. Following the policy reforms, the firm went through a severe deterioration process during the mid 1990s. Such evidence supports some of the arguments against the structural reforms (Section 2).

Indeed, during the 1980s, there were Brazilian innovative firms in the electronics industry in Manaus (e.g. Sharp Brazil, Gradiente, and Itautec). On the basis of the capability framework used here, by the late 1980s such firms had built up capabilities at Level 2 and 3 for process and production organization and product-centered activities. For instance, an in-depth case-

5 I am grateful to Satoko Yasuda for this point.
6 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.
study based on a long-term coverage (see Mota, 2002) indicates that Sharp Brazil was able to design and develop the first VCR in Brazil drawing on its own product-centered innovative capability (Levels 4 to 5). The firm operated quite independently from the parent company in Japan. By the mid 1980s Sharp Brazil had created a respectable organizational structure in Manaus for product design and development.

However, during the mid 1990s Sharp Brazil began to deteriorate and was permanently closed down in 2001: the firm was undermined by fierce power struggles and mis-management that followed the death of its founder in the mid 1990s (Mota, 2002). Other firms like Gradiente and Itautec-Philco still exist and are competitive. For instance, data from in-depth study of Gradiente shows how the firm re-organized its internal technological activities in order to improve upon its innovative performance to face up to foreign competition (see Silva, 2002). Thus, although the policy reforms of the early 1990s swept away some firms from the industry, it is important to note that there also were other factors such as mis-management both at the government policy level (e.g. the case of electronics policy (MCT, 2002)) and at the level of firms, as illustrated by the above evidence.

Strikingly, nine out of 10 top managers and industrial leaders interviewed during the fieldwork about their perceptions of the structural reforms pointed out that these were some of the best policy measures ever taken by the Brazilian government. As one industry association leader in Manaus put it: ‘Had Brazil not taken those measures during the early 1990s, the Brazilian industry and Manaus would be outdated and uncompetitive today. And consumers would be paying a high cost in terms of product variety, quality, and price’.

6.2 Types and levels of technological capability in the sampled firms

Table 3 summarizes 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 3 shows that all 46 sampled firms had mastered basic operations across the three technological functions.
Table 3. Number of sampled firms that have reached specific levels of technological capability \(^{(a)}\)

<table>
<thead>
<tr>
<th>Types and levels of technological capabilities by sector</th>
<th>Electro-electronics (EE)</th>
<th>Motorcycle and bicycles (MCB)</th>
<th>Suppliers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Process and production organization</td>
<td>Product-centered</td>
<td>Equipment-related activities</td>
</tr>
<tr>
<td>Mastery of basic operations Level 1</td>
<td>18 (100%)</td>
<td>18 (100%)</td>
<td>18 (100%)</td>
</tr>
<tr>
<td>Mastery of basic operations Level 2</td>
<td>18 (100%)</td>
<td>18 (100%)</td>
<td>18 (100%)</td>
</tr>
<tr>
<td>Basic innovation Level 3</td>
<td>18 (100%)</td>
<td>13 (72%)</td>
<td>9 (50%)</td>
</tr>
<tr>
<td>Intermediate innovation Level 4</td>
<td>14 (78%)</td>
<td>3 (17%)</td>
<td>2 (11%)</td>
</tr>
<tr>
<td>High-intermediate innovation Level 5</td>
<td>11 (61%)</td>
<td>0 (not attained)</td>
<td>0 (not attained)</td>
</tr>
<tr>
<td>Advanced innovation Level 6</td>
<td>0 (not attained)</td>
<td>0 (not attained)</td>
<td>0 (not attained)</td>
</tr>
</tbody>
</table>

Source: Derived from the empirical study; Note: \(^{(a)}\) Situation during the fieldwork period.
Up to the late-1980s the great majority of firms in Manaus supplied only the Brazilian market. Export represented only 1% of its output. Data from interviews with industry and academic leaders in Manaus and São Paulo suggested that a closed and captive domestic market and the absence of any institutional framework to protect consumers’ rights up to 1990 fuelled manufacturing firms with a low level of concern for final product quality. As one top manager pointed out: ‘Up to the late 1980s the majority of industries [in Brazil, in general] suffered from a technological sloth; when the economy was opened up, several firms woke up to the reality of real competition and began to run for their survival; the Brazilian industry needed that shake-up to wake up to a new world reality’.

As one of the leading organizations 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-centered 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.

In terms of the test as to whether there were significant differences between TNC-subsidiaries and local firms in terms of capability level, Table 4 shows that within the EE sample, no significant differences between TNC-subsidiaries and local firms in terms of capabilities for process and production organization and equipment-related activities exist. However, there were significant differences (p<0.05) between foreign and local firms with respect to product-centered-capability: capability levels of local firms were deeper than those of foreign firms for this function.7

Table 4. Kruskal-Wallis test for types and levels of technological capability and ownership (local foreign) in the sampled firms

<table>
<thead>
<tr>
<th></th>
<th>Electro-electronics firms</th>
<th>Motorcycle and bicycles firms</th>
<th>Supplier firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proc</td>
<td>1.412</td>
<td>2.444</td>
<td>8.904</td>
</tr>
<tr>
<td>Prod</td>
<td>3.911</td>
<td>0.505</td>
<td>4.586</td>
</tr>
<tr>
<td>Equip</td>
<td>0.048</td>
<td>2.000</td>
<td>9.134</td>
</tr>
<tr>
<td>Df</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Asymptotic significance</td>
<td>0.235</td>
<td>0.118</td>
<td>0.003**</td>
</tr>
<tr>
<td></td>
<td>0.048*</td>
<td>0.477</td>
<td>0.032*</td>
</tr>
<tr>
<td></td>
<td>0.827</td>
<td>0.157</td>
<td>0.003**</td>
</tr>
</tbody>
</table>

Notes: (*) Association significant at the 0.05 level; (**) Association significant at the 0.01 level.

7 For the statistical analysis, the non-parametric Kruskal-Wallis test was used. This test was chosen because of the small sample size of firms and because of the ordinal scale of capability levels.
In relation to the MCB sample, Table 4 shows no difference between local and foreign subsidiaries across all three types of technological capability. In contrast, evidence from the sampled supplier firms shows that capability levels accumulated in TNC-subsidiaries were deeper than those accumulated in local firms. Table 4 shows significant differences between capability levels attained in local supplier firms and those attained in foreign supplier firms across all three functions: process and production organization (p<0.01), product-centered (p<0.05), and equipment-related (p<0.01).

6.3 Rate (speed) of capability development in the sampled firms

In the light of Section 3, the measurement of such rates involves the historical period that goes from each firm’s start-up time up in Manaus to the end of fieldwork in 2005. The length of time that the sampled EE, MCB, and supplier firms took to learn and carry out, independently, activities in one technological capability level before moving to another specific level is represented in Figures 1 to 3. Detailed evidence of such rates is shown in Appendices C to E.

![Figure 1. Mean speed (number of years taken) to move through different technological capability levels in the EE sampled firms](image-url)
The evidence indicates that all the firms took a long time to move from the basic operations level (Level 1) to the renewed basic level (Level 2) in all three technological functions. The following evidence provides some illustrative concreteness to the movement between capability levels for the three technological functions in the sampled firms.

6.3.1 Capability for process and production organization activities
At capability Level 3 firms were able to carry out, independently, activities like transfer
design to manufacture; optimize process layout and flow; time, motion and ergonometric
studies (filming), building quality systems (e.g. ISO 9002, 14001), develop in-line QC; on-
line, real-time integrated production control systems; carry out material requirements planning
(MRP); undertake detailed failure analysis (FMEA), six Sigma, and SPC; JIT delivery
between parts and component suppliers and consumer electronic firms and JIT within
production operations (Kanban). However, once they have reached Level 4 capability they
engaged in flexible and multi-skilled production (cell-based robot systems and product
assembly), innovative flexible process layout and workers; re-engineering of process from
other industries in other countries (e.g. a local supplier that adapted a robot from an Italian
furniture firm to achieve high-speed and high-precision in coating and painting of plastic
components for EE firms); business re-organization and innovative management structures;
and software development for process control.

At Level 5 capability, there was reverse knowledge flow from Manaus to other foreign
subsidiaries (e.g. providing plant set-up and training-for-production and on-line, real-time
automatic sensors for process flow to global sister plants). This seems to suggest that the
attainment of this capability level, especially for the sampled TNC-subordinates, 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).

6.3.2 Capability for product-centered activities

Firms that have developed innovative capability levels between Levels 3 and 5 were able to
carry out activities like some modifications to product designs: product-process interface, ISO
9001; engagement in new product development efforts with São Paulo, Singapore, US, or
Japan; transfer software into integrated circuit (IC), feature design, customized IC design, new
product development; prototyping, and on-line product design transfer.

By the early 1980s, one large electronic Brazilian firm, Gradiente, had built up Level 3
capabilities for products and was able to carry out cosmetic designs and mechanical projects.
By the mid 1980s, following an organizational restructuring, the mechanical and electronic
project units were created to support and speed up product design and development activities.
As a result, the annual number of products developed internally, that had evolved from three
to 12 during the 1972-81 period, changed from 21 to 49 during the 1982-88 period.

By the mid 1990s, the company’s organizational structure was again changed to intensify
product activities. Specific engineering units were created for audio, video games, systems,
hi-ends, and acoustic. One unit dedicated to product design. Additionally, a committee was
created to give a final word to products line-up and design styles. Consequently, the number
of products developed within Gradiente during the 1989-2000 period evolved from 40 to 90,
and reached 122 in 1998. The average number of months it took to develop a product
decreased from 24 (early 1970s) to 10 (by 2000). By the mid 1990s, nearly 20 years after its
inception in Manaus, the firm had accumulated Level 4 product capability and Level 5
capability for process and production organization. Another Brazilian firm, Itautec-Philco,
built up Level 5 capability for process and production organization, but Level 3 for product
activities. This qualitative evidence helps explain in part, the innovative capability levels
attained by local firms in contrast to the foreign ones, as mentioned in Section 6b.

One small local firm has become a supplier of on-order products to other larger EE and MCB
local and foreign firms in Manaus. The firm started up in Manaus in the early 1990s in the
metalworking business. Its owner, a mechanical engineer who had worked in Embraer (the Brazilian aircraft maker) moved to Manaus to start up his own business. The firm began by providing equipment maintenance services to EE and MCB firms. By the time of the fieldwork, the firm employed 12 skilled technicians (all of them recruited in Manaus) and had become a respected provider of robots’ arms and other components and engaged in automation projects with EE, MCB and other firms in Manaus.

As revealed in fieldwork interviews, the engagement of this firm in more sophisticated technical activities was associated with the stimulus provided by its users: the local firms and, to a significant extent, the foreign supplier firms. These gradually increased the technical levels of their orders, challenging and pushing the small firm into more sophisticated activities. As the firm’s owner put it: ‘Today we feel confident and capable of meeting our customers’ rigorous technical expectations’.

Similarly, a small local firm (around 20 workers), owned by a couple of chemical engineers, who had moved from the Northeastern Brazil into Manaus during the early 1990s has become a key supplier of parts galvanization for Honda. As they pointed out: ‘In the beginning it was tough to meet their quality expectations, but they gave us a tremendous encouragement. They usually come here, share problems and help us improve our work.’ This is additional evidence that helps explain the innovative product capability levels found in the local firms (Section 6b).

6.3.3 Capability for equipment-related activities

In terms of equipment-related capability (tooling, stamping, and molding), EE firms that have developed innovative capability at Levels 3 and 4 have been able to carry out, independently, the development of own testing jigs and burn-in equipment, own development automatic sensors in conveyor systems, vision for testing; mechanical, pneumatic devices to speed up process flow. Additionally, they have been able to carry out automated movement of incoming, work-in-progress (WIP) and finished goods and patented their own developed automated test equipment and multi-product testing software tools (own TestCAD).

As far as the MCB sample is concerned, Honda provides a striking example. Within around 25 years it moved from Level 1 to 6 equipment capability (although not completely). During the fieldwork, the company was building up its product design and development centre in Manaus and a mold maintenance unit. As revealed during interviews, the idea was to evolve into a unit for mold design. There was a previous initiative from industry associations to build up a mold design and maintenance center in Manaus to reduce dependence on South Korea and Portugal. The idea had not materialized by the time the fieldwork was completed.

One of Honda’s managers described the company’s reaction: ‘We could not afford to wait. We have decided to go on and build our own mold center to gain autonomy’. Interviews with Honda’s top managers in Manaus suggest that this idea is part of a broader corporate scheme that combines ‘globalization’ and ‘localization’ strategies. This also suggests that the firm has been building an organizational basis to support further advanced product and equipment-related innovation activities. As pointed out by one of the managers, Honda Manaus is in a strategic position to engage in product innovation activities to supply specific products for consumers in the Americas. In contrast, five sampled MCB firms and four suppliers had not moved from Level 1 to 2 by the time of the fieldwork. Indeed, one local motorcycle firm, that had entered the industry during the mid 1990s stimulated by the favorable currency and
lowered import rates, was experiencing a serious financial and market crisis at the time of fieldwork.

As far as the two old domestic bicycle firms were concerned, both had started up in Manaus in the mid 1970s. Although they had been the largest and leading firms in the Brazilian market for decades, both entered the 1990s with Level 1 capability for the three technological functions. Following the policy changes of the early 1990s, both firms almost collapsed as they could not cope with foreign competition. A Brazilian investor took over one of the firms in the mid 1990s and implemented a far-reaching corporate restructuring to help keep the firm competitive.

On the basis of the metric for technological capability used here, it was not until the early 2000s that this bicycle firm was able to accumulate Level 2 capability for process and production organization. It was not until 2005, nearly 20 years after its inception in Manaus that such firm moved into Level 3 capability for this technical function and Level 2 for product and equipment-related activities. The maximum capability level attained by the second firm was Level 2 for all three technological functions, this seemingly lack of progress may account in part for the erosion in the company’s market share.

Up to the early 1990s both bicycle firms operated in a highly protected environment that did not stimulate them to pursue innovative activities and to improve their performance by benchmarking against foreign competitors. As an industry specialist pointed out: ‘When the economy was opened up a large number of foreign bicycles poured into Brazil. We then realized how weak local firms were in terms of technical efficiency, product quality, and price, as compared to international competitors’.

To sum up, although some sampled firms were indeed stuck at Level 1 capability for specific technological functions, the great majority of them – both TNC-subsidiaries and local firms – have constantly upgraded their capabilities to carry out different innovative activities, particularly from the early 1990s. In line with Ariffin (2000), at the lower capability levels, the average rates were not significantly different across all firms in the EE, MCB, and suppliers samples for the three technological functions. The firms, on average, took longer to move from production capability levels to basic innovative level (Level 3) and beyond. Even though there is not much difference in the mean capability development rates of lower technological capability levels (Levels 1 and 2), there is considerable diversity in the capability building rates of firms, as reflected in the high standard deviations in Appendices C to E.

Considering that 55.5% of the sampled EE and MCB firms began their operations in Manaus from the mid 1970s to the late 1980s, such evidence suggests that, with a few exceptions, the capability of most of these firms were confined to basic operating levels during that period. This interpretation agrees with Teitel’s (1992) view that up to the late 1980s, most firms that operated in highly protected environments in several developing countries, including Latin America, were not building technological capability for competitive sustainability in the global economy.

On average, capability development rates decreased over time as firms moved through innovative levels (Level 3 and beyond). However, although this evidence reflects an acceleration of firms’ capability development, such movement has led some firms to reach Level 5 as their maximum technological capability level. Indeed, one firm (Honda) has
attained Level 6 (albeit not completely). As noted earlier, one of the limitations of this paper is that it does dwell on the key influencing factors (e.g. intra-firm learning processes and inter-firm knowledge links) that might have affected these rates. Nevertheless, the evidence suggests a positive change in the pattern of capability development during the outward-looking policy regime in relation to the previous system.

6.4 Export performance: industry-level evidence

Although the relationship between innovative technological activities and export performance has been explored in different ways in previous studies (e.g. Dosi et al., 1990; Amable & Verspagen, 1995; Rasiah & Gachino, 2004; Rasiah, 2006), there is no consensus in terms of the nature and direction of causality. On the one hand, firms operating in an outward-looking industrial regime would be stimulated to thrive in the international market, thus favoring their engagement in innovative activities (Braga & Willmore, 1991); on the other, innovative activities would explain export performance depending on sectors’ technological intensity (Montobbio & Rampa, 2005).

By 1990 exports represented only 1% of the total revenue of the Industrial Pole of Manaus; by 2005, 14%. During the 1988-2004 period, while domestic sales increased by 5.9% annually on average, export sales increased at the rate of 19.8%. The fastest rates of export growth were achieved from the mid 1990s. Table 5 shows the sampled firms’ market orientation.

Table 5. Distribution of sampled firms on the basis of their market orientation

<table>
<thead>
<tr>
<th>Type of sampled firms</th>
<th>Exporting firms</th>
<th>Non-exporting firms</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TNC-sub.</td>
<td>Local</td>
<td>Sub-total</td>
</tr>
<tr>
<td>Electro-electronics</td>
<td>11</td>
<td>2</td>
<td>13 72%</td>
</tr>
<tr>
<td>MCB</td>
<td>2</td>
<td>1</td>
<td>3 33%</td>
</tr>
<tr>
<td>Suppliers</td>
<td>3</td>
<td>0</td>
<td>3 16%</td>
</tr>
<tr>
<td>Totals</td>
<td>16</td>
<td>3</td>
<td>19 41%</td>
</tr>
</tbody>
</table>

Source: Derived from the empirical study.

Table 6 shows the results of a statistical significance test of differences between exporting and non-exporting sampled firms in terms of capability levels. Although the limitation here is that such differences are not explained, the association test suggests that exporting firms were those with deeper capability levels. Within the EE sample, export levels correlated highly to innovative capability, particularly for equipment-related activities (p<0.05). Within the MCB and supplier samples exports were highly significant to innovative capability for process and production organization (p<0.05), products (p<0.05), and equipment-related activities (p<0.01). While this evidence supports the conclusions in Montobbio & Rampa (2005) and Rasiah (2006), it moves a bit further to capture different types of association between export performance and capability levels across technical functions within firms of high and medium technology sectors, such as EE and MCB firms.
Table 6. Kruskal-Wallis test for technological capability levels and export performance

<table>
<thead>
<tr>
<th></th>
<th>Electro-electronics firms</th>
<th>Motorcycle and bicycle firms</th>
<th>Suppliers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proc</td>
<td>Prod</td>
<td>Equip</td>
</tr>
<tr>
<td>Chi-square</td>
<td>2.914</td>
<td>0.284</td>
<td>4.471</td>
</tr>
<tr>
<td>Df</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Asymptotic</td>
<td>0.088</td>
<td>0.594</td>
<td>0.034*</td>
</tr>
</tbody>
</table>

Notes: (*) Association significant at the 0.05 level; (**) Association significant at the 0.01 level

Going back to Table 5, we observe that a striking 84% of the sampled exporting firms are TNC-subsidiaries, whereas only 16% are local. This is especially noteworthy if we consider the fact that all the firms have operated under an outward-looking industrial regime since the early 1990s. This evidence corroborates that of Rasiah & Gachino (2004) with respect to an underdeveloped area and seems to underscore the fact that longer-established TNCs have been able to take advantage of the global spread of their operations to create an international network of specialized subsidiaries. Depending on the assignment given, subsidiaries may evolve from local to wholly exporting capabilities (Cantwell & Pitt, 1999; Cantwell & Mudambi, 2005). As suggested in the various interviews, foreign subsidiaries take advantage of their groups’ international marketing, commercial, and logistics structure to outperform local firms in exporting activities.

Additionally, it is important to clarify the fact that, historically, the Industrial Pole of Manaus was oriented towards the domestic market and that there still exist obstacles to export activities in Brazil despite all those industrial policy reforms. As stated by one interviewee: ‘Despite the official rhetoric, Brazilian firms (especially medium-sized and small) still faces several barriers to export: taxation, lengthy administrative procedures, and lack of information.’

6.5 Results of regression analysis

Table 7 presents some results of a regression analysis of the effects of selected factors (independent variables) on the rate of firm-level capability development for specific technological functions (dependent variable). For this analysis, three sets of models were specified to test the effect of these independent variables on capability development rate for each of the three technical functions (Models 1-4, process and production organization; Models 5-8, product-centered; and Models 9-12, equipment-related).8

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8 These independent ‘variables’ involve: (i) sectors (EE, MCB, and suppliers); (ii) maximum capability level attained by each firm; (iii) ownership (local or foreign); (iv) firms’ entry time (before or after 1990); (v) firms’ market orientation (exporting or non-exporting).
The first model in each set (Models 1, 5 and 9) includes only ‘sector’ and ‘maximum capability level attained by each firm’. The second model in each set adds ownership (Models 2, 6, and 10), while the third model introduces firms’ entry time (Models 3, 7 and 11). Finally, the fourth model (4, 8 and 12) includes firms’ market orientation. The rate of capability building was counted on the basis of the number of years each firm took to move from the completion of Level 1 up to the maximum level attained. Firms that did not move beyond Level 1 were not considered in this analysis. The main results are commented on as follows.
Table 7. Regression analysis of the effects of selected factors on the rate of firm-level capability development for specific technological functions

<table>
<thead>
<tr>
<th>Some selected factors</th>
<th>Process and production organization</th>
<th>Product-centered</th>
<th>Equipment-related</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
</tr>
<tr>
<td>(Constant)</td>
<td>0.239</td>
<td>0.220</td>
<td>0.591</td>
</tr>
<tr>
<td>Sectors: a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE b, c</td>
<td>0.228</td>
<td>0.321</td>
<td>-1.076</td>
</tr>
<tr>
<td>MCB b, c</td>
<td>1.162</td>
<td>1.040</td>
<td>-0.786</td>
</tr>
<tr>
<td>Max. capability level attained by each firm c</td>
<td>2.082***</td>
<td>2.232***</td>
<td>1.555***</td>
</tr>
<tr>
<td>Ownership b, e</td>
<td>-1.022</td>
<td>-0.111</td>
<td>-0.423</td>
</tr>
<tr>
<td>Firms’ entry time b, d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market orientation (exporting/non-exporting) b, f</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.341</td>
<td>0.353</td>
<td>0.777</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.292</td>
<td>0.288</td>
<td>0.754</td>
</tr>
</tbody>
</table>

a This regression model required one dummy to be dropped to avoid the dummy variable trap. I dropped the dummy for ‘suppliers’ as this sector has different kinds of transactions with both EE and MCB firms.
b Dummy variables; c control variables
d Firms that were in operation before 1990 were coded 1 and firms that started up after 1990 were coded as 0.
e Foreign firms (TNC subsidiaries) were coded 1 and local firms were coded as 0.
f Non-exporting firms were coded 1, while exporters were coded as 0.

*p < 0.10 ; ** p < 0.05 ; *** p < 0.01. All tests are one-tailed.

Dependent variable: rate or speed (time measured in terms of number of years spent) to move from the completion of Level 1 capability up to the maximum level of capability attained by each sampled firm.

The presence of multi-collinearity was checked. All VIFs (variance inflation factor) are lower than 2.5.
First, as mentioned in Section 3, there are inter and intra-sector differences in terms of innovative capabilities (Pavitt, 1984; Dosi, 1988; Malerba, 2005). However, there is a scarcity of empirical evidence, particularly within the late-industrializing literature, relative to inter-sector, inter-firm, and intra-firm commonalities and differences in terms of the rate of capability development (Bell, 2006).

Indeed, the results in Table 7 suggest that the fact of firms being either EE, MCB or suppliers did not affect the rate of capability development for process and production organization and equipment-related activities (Models 1-4 and 9-12, respectively). There are, however, statistically significant differences related to product-centered activities in Models 5 and 8 (EE firms, \( p < 0.05 \); MCB firms, \( p < 0.10 \)). Specifically, in relation to supplier firms, EE firms took, on average, 2.28 more years to accumulate their product-centered capabilities, whereas MCB firms took 2.25 years more than suppliers to develop this type of capability (Model 5), holding other variables constant. One possible explanation is that EE and MCB firms share common traits like the global spread of their operations, consumer-orientation, and intensity of product-based activities.

Second, considering that 1990 was a crucial year in terms of fundamental industrial policy changes in Brazil (see Table 2), I examined whether firms’ entry time in Manaus (before or after 1990) has exerted any influence on the rate of their capability building. When introducing this factor, the results show a strong and positive influence of firms’ entry time on the rate of capability building for the three technological functions (\( p < 0.01 \), Models 3, 7 and 11). For instance, firms that entered the industry before 1990 took nearly six years more than firms that entered after 1990 to develop capabilities for process and production organization (Model 3, \( p < 0.01 \)). This appears to suggest that when entering the industry under an environment that was already competition oriented, firms were more stimulated to make efforts to reduce costs, improve products and/or introduce new ones, speed up their production processes by drawing on and/or developing their innovative capabilities, than firms that operated under a competition-free environment (or ‘comfort zone’). Nevertheless, the introduction of the variable ‘entry time’ (which indicates different policy regimes), makes the relative heterogeneity across sectors (discussed in the preceding paragraph) insignificant, from the perspective of product-centered capabilities.

Third, taking into account the cumulativeness and path-dependency properties of the capability development process (Nelson & Winter, 1982; Dosi, 1988; Lall, 1990, 1992; Bell & Pavitt, 1995) and results of previous empirical studies on capability building rate (e.g. Ariffin, 2000; Figueiredo, 2001; Tacla & Figueiredo, 2006), I tested the relationship between the maximum capability level attained by each firm and the number of years it took from the completion of Level 1 up to the maximum capability level achieved.9

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9 In the light of the framework for capability used here, there were variations across firms in terms of their maximum capability level attained and the number of years taken to attain such level. For example, one sampled firm took nearly 20 years to reach Level 2 capability for process and production organization as its highest capability level; another firm took less than 10 years to attain Level 4 capability; whereas a third firm took around 25 years to reach Level 5 as its maximum capability level for this function. This intricate evidence of rates of firm-level capability development compelled me to examine the relationship between the maximum capability level reached by each firm and the number of years taken to reach it.
As Table 7 shows, the maximum capability level attained by each firm had a positive and statistically significant impact \( (p<0.01 \text{ for all models}) \) on the rate of capability accumulation for the three technological functions. For example, the result of Model 1 shows that in terms of capability development rate for process and production organization, for each maximum capability level attained there is an estimated increase of 2.08 years, on average, to achieve the subsequent maximum level in the metric (Appendices A, B and Table 3), regardless of the firm being EE, MCB or suppliers, holding other variables constant. Conversely, the estimated time-scale was raised to nearly four years to attain the next maximum capability level for product (Model 5) and equipment activities (Model 9). \(^{10}\) This helps explain the findings in Sections 6b-c, mainly the systematically decreasing rates of innovative capability accumulation, particularly for process and production organization in all sampled firms (Figures 1-3).

To some extent, these findings offer a tangible idea of the time-scale involved in firm-level capability development. Specifically, such results provide managers and policy-makers with a concrete notion of the time-frame to materialize the returns, in terms of innovative capability building, that they expect from their efforts on learning over time.

Fourth, Table 7 shows that there was no significant effect of ownership on the rate at which these firms moved through capability levels for these three technical functions. While the findings point to some differences between local and foreign firms in terms of existing types and levels (‘stocks’) of capabilities (especially EE and suppliers – Section 6b, Table 4), no difference between local and foreign firms was observed with regard to the rate at which these capabilities have been developed.

Finally, extending the analysis of the relationship between firms’ export orientation and technological capability (Section 6d), Table 7 shows that the fact of being exporting or non-exporting only had significant impact on the capability development rate for process and production organization (Model 4, \( p<0.10 \)). This result indicates that exporting firms took three years less than non-exporting to move from the completion of capability Level 1 up to the maximum capability level for process and production organization. This may be because as exporting firms are more exposed to specific needs of the international markets they supply, they need to respond quickly to and/or anticipate the changes and trends in such markets. This, in turn, appears to be reflected on the speed at which they adapt and upgrade their process and production organization capabilities to meet new requirements of product design. This further suggests that exposure to foreign competition is relevant for firms’ innovative capability building.

The key findings of this study are summarized as follows:

(1) The evidence suggests a positive change in the pattern of technological capability accumulation in the majority of the sampled firms following the structural reforms of the early 1990s. Different from the pattern in the period prior to the reforms, most of these sampled firms moved into the development of innovative capabilities from the early 1990s with firm-specific variations in terms of manner and rate. This finding supports the view that firms’ technological behavior is a set of responses to stimuli in its environment (Bell et al., 1982) and the association between degree of protection

\(^{10}\) It should be remembered from Table 3 and Figures 1-3 that just one firm reached the maximum level in the metric (Level 6) and, even so, in an incomplete manner.
and pattern of technological behavior (Bell, 1984). It also is consistent with the point that outward-looking regimes do foster innovative technological efforts (Lall, 1990, 1992).

(2) Indeed, individual firms’ responses differed across the three sectors, across firms of the same sector, and across specific technical functions within firms in terms of the direction and rate of capability development. This, in turn, seems to reflect specific learning strategies of each firm. Even though the issue of intra-firm learning processes was not examined here, the evidence seems to suggest that although a dramatic change in the policy regime may be necessary to stimulate firms’ innovative activities, the final result will ultimately depend on the way individual firms carry out their capability building efforts (Nelson & Winter, 1982; Dosi, 1988; Lall, 1992; Bell & Pavitt, 1993; Figueiredo, 2001). Policy makers can thus not afford to take firms’ responses to policy changes for granted.

(3) The evidence of commonalities and heterogeneities in the sampled firms’ technological capabilities are consistent with classical conceptual frameworks (e.g. Nelson & Winter, 1982; Pavitt, 1984; Dosi, 1988; Malerba, 2005 among others) and with various empirical studies on innovation in both early and late-industrializing contexts, especially those based on static designs and aggregated data and analyses based on conventional indicators (e.g. R&D expenses and patenting statistics). However, most of such existing studies miss out important nuances of inter and intra-firm heterogeneities and commonalities in capability development process for specific technological functions across different points in time. Such nuances are crucially important to the understanding of the dynamics of capability building in latecomer contexts. The findings here add new evidence and insights to studies concerned with the rate (speed) of firm-level of capability development in the late-industrializing context (Katz, 1987; Ariffin, 2000; Figueiredo, 2001; Tacla & Figueiredo, 2006; Bell, 2006).

(4) From a static standpoint, the results here support the conclusions in Costa & Queiroz (2002) and Kannebley Jr. et al. (2005) relative to differences between foreign and domestic firms as far as technological capabilities are concerned. This paper however goes further to capture what Ariffin (2000) identifies as intra-firm diversity not only in terms of types and levels (‘stocks’) of capabilities, but in terms of dynamics of capability development for specific technological functions across foreign and local firms. From a dynamic perspective, and in line with Ariffin (2000), the results indicate no significant difference between local and foreign firms in terms of capability development rate for specific technological functions. This study goes a short step further than Ariffin (2000) in that it tests such a relationship in firms other than those in the electronics industry.

(5) This paper offers an alternative perspective to studies that tend to adopt a negative view of firms’ technological activities following the change into an outward-looking industrial regime during the early 1990s in Southern Latin America, especially in Brazil (e.g. Ferraz et al., 1996; Haguenuer et al., 1998; Coutinho, 1997; Narula, 2002; Cimoli & Katz, 2003; Rocha & Kupfer, 2002). Because such studies are based on aggregated analyses drawn from government censuses (based on conventional indicators), the design and evidence on which they are based do not capture (or have
not captured so far) the subtleties of gradual changes in the patterns of firm-level technological capability development that have been occurring since the 1990s.

(6) With respect to macro-level studies that point to positive implications of the early 1990s reforms for industrial performance (e.g. Edwards, 1998; Moreira & Correa, 1998; Hay, 2001; Ferreira & Rossi, 2003), this paper moves a step forward by offering inter-sector, inter and intra-firm evidence that is important to obtaining a more realistic picture of what has been taking place in specific industrial segments in a developing country like Brazil as a result of policy changes over time. On the basis of the foregoing, it would be quite naïve to assume that the various sectors and firms would react in a homogenous way to given policy changes.

7. CONCLUSIONS AND POLICY IMPLICATIONS

This paper sought to examine the pattern of firm-level technological capability development in the light of changes in industrial policy regimes. These issues were examined based on extensive fieldwork that involved the gathering of first-hand intra-firm evidence from a sample 46 local and foreign firms located in the under-researched Industrial Pole of Manaus (Northern Brazil) during the 1970s-2005 period. This study reveals that there are diverse inter-sector, inter-firm, and intra-firm responses in terms the manner and rate of capability development for specific technological functions. This kind of firm-level scrutiny under different industrial regimes is largely missing in the literature. The study also demonstrates the extent to which the analysis of firm-level technological capability can be taken when it is not restricted to aggregated data of standard R&D expenditures, patents, personnel, and scientific publications statistics.11

The results show that the patterns of firm-level capability development and, to some extent, export performance, exhibit positive responses to the changes in industrial policy regimes as a result 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 4). In the absence of such government policy, all these firms would probably not even be there in the first place.

Nevertheless, the evidence relative to the (slow) pattern of firm-level capability development that preceded the reforms of the early 1990s suggests that such government policy alone proved not sufficient for stimulating rapid industrial development. Indeed, a combination of government policy, foreign competition, and intra-firm capability building efforts proved essential for speeding up capability development in some of the firms examined in this paper. Additionally, the evidence of the variations in inter and intra-firm manner and rates of capability development suggests that the policy changes notwithstanding, industrial technological development largely depends on the way in which each specific firm responds to such institutional changes.

11 I thank one of the referees for underscoring such strengthen of this paper.
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 organizational activities, and also dissemination of successful experience, particularly those of local suppliers.

As pointed out in Section 2, this study has some weaknesses. For instance, it draws on a relatively small sample of firms located in a specific region of one country. 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. Although based on extensive fieldwork, the study makes no attempt at building proxies for policy measures to be used in the analysis as for instance, the perception of managers on the nature and implications of market protection and foreign competition over time.

Finally, after nearly 20 years of the structural reforms, it is about time that future studies moved beyond the polarized perspectives that glorify and/or profane either ISI or the liberalization policy regimes, to more refined analyzes of the key factors that are likely to influence the acceleration of firms’ innovative capability development in the context of late-industrialization under global competition. A combination of industry-level aggregated analyzes 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.

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