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## **Innovation capabilities in the Brazilian automobile industry: a study of vehicle assemblers' technological strategies and policy recommendations**

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**Abstract:** This paper is concerned with the development of technological capabilities in the Brazilian subsidiaries of multinational assemblers in Brazil, particularly their involvement in Product Development (PD). The paper addresses the following issues: What roles have vehicle assembly subsidiaries played in building up local technological capabilities in PD in Brazil? How complex are such activities? Are innovative technological capabilities being accumulated as result of the involvement of subsidiaries with PD? Complementary, the paper addresses the question of what are the implications of assembler's PD location strategy for local auto-parts producers. The paper concludes with policy implications and discussion on the benefits of decentralisation.

**Keywords:** automotive industry; Brazil; PD; product development; technological capabilities decentralisation; transnational corporations' subsidiaries.

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## 1 Introduction

Globalisation in the automobile industry has seen the widespread diffusion of the adoption of the practice of global vehicle platform, which has been driving product design and auto-parts sourcing. Major assemblers have organised product portfolios and supply chains based on global platforms and modules/systems of components.<sup>1</sup> Such practices have increased the scope for sharing auto parts between different models, therefore increasing economies of scale, a critical aspect of competition in the industry. However, the dissemination of such design principle does not imply that all assemblers have adopted the same product strategy or the same organisation of Product Development (PD). Different product and PD strategies have been pursued by global assemblers located in Brazil. They have followed different routes for organising PD, varying from *centralisation* in headquarters or in European subsidiaries, to *decentralisation* of PD, with greater autonomy for the Brazilian subsidiary.

This paper is concerned with the development of technological capabilities in the Brazilian subsidiaries of multinational assemblers in Brazil, particularly their involvement in PD and the related acquisition of technological capabilities. It addresses the following issues: What roles have vehicle assembly subsidiaries played in building up local technological capabilities in PD in Brazil? How complex are such activities? Are innovative technological capabilities being accumulated as result of the involvement of subsidiaries with PD? Complementary, the paper addresses the question of what are the implications of assembler's PD location strategy for local auto-parts producers.

These issues are discussed in the light of the empirical findings produced by two research projects on the role of Transnational Corporations' (TNCs) subsidiaries in vehicle assembly in Brazil.<sup>2</sup> The empirical work included eight car assemblers: the major, long-term established assemblers General Motors of Brazil (GMB), Volkswagen (VW), Fiat of Brazil, Ford of Brazil; and the new entrants to Brazil in the late 1990s such as Renault, PSA Group, Toyota and Honda. In addition to car assemblers, fieldwork has investigated the experience of the Volkswagen Truck and Bus (VW-TB) division, whose

main plant and PD facilities are located in Brazil. The main findings support the initial assumption that assemblers have been following different PD strategies, from more centralised to more decentralised, according to headquarter decisions, which has resulted in variations in local PD capabilities. On the one hand, major assemblers, which are the incumbents operating for long time in Brazil, have adopted product design policies oriented towards emerging countries (like Brazil), local engineering staff have increased and have been working with the R&D centres abroad. On the other hand, as for newcomers – particularly the Japanese – product adaptation to local requirements has been carried out by the headquarters abroad with much less input from Brazilian engineering. In the case of the VW truck subsidiary, which is independent from the VW car operation, the Brazilian subsidiary is the major centre of design, engineering and manufacturing. Hence, there is significant heterogeneity in the vehicle assemblers' trajectories in terms of technological upgrading.

This research contributes to the recent stream of research reviewing the role of TNCs' subsidiaries in the process of technological learning in newly industrialised economies. Research on Malaysia (Ariffin and Bell, 1999), Singapore (Amsden et al., 2001), India (Reddy, 1997) and Brazil (Quadros et al., 2001; Costa and Queiroz, 2002; Ariffin and Figueiredo, 2003) suggests that TNCs' subsidiaries should not be treated as a homogenous group, since they vary in their technological strategies, efforts and derived competencies.

The paper draws on Lall's (1992) and Bell and Pavitt's (1995) framework to capture and classify the types and levels of technological capabilities and learning in newly industrialised countries. According to such frame, the building up of innovation capabilities goes through various stages, running from a basic level (basic innovation capabilities) through intermediate levels (intermediate innovation capabilities) up to more complex and advanced levels that enable the firm to promote innovative changes (advanced innovation capabilities). This was later modified by Ariffin and Bell (1999) to analyse technological capabilities in TNCs' subsidiaries established in developing countries.

The paper is organised as follows. Section 2 deals with the evolution of the automotive industry in Brazil. Section 3 deals with the Brazilian government policies focusing on this sector, specifically the Automotive Regime (AR) Policies. Section 4 analysis R&D and technological capabilities in the Brazilian automotive industry. Section 5 focuses on the PD competencies in assemblers in Brazil and how vehicle assembler subsidiaries in Brazil have adopted different paths to the globalisation of products and PD, each having different impacts on local product policies and distinctive implications for the development of local innovation capabilities. Section 6 concludes with policy implications and with the discussion of decentralisation of PD activities adopted by leading assemblers for Brazil.

## **2 The Brazilian context and the role of assemblers' subsidiaries**

The technological capabilities of assemblers' subsidiaries in Brazil have arisen as a result of a long process of development of local operations, particularly the search for technical solutions to meet local demand, either related to technical differences in materials, fuels and road conditions or to distinct consumer preferences. Thus, the building of capabilities by Brazilian automotive engineering has been the result of a learning process in adapting and, more recently, designing and developing vehicles suitable for local conditions.

However, to understand the implications of such conditions, it is important to analyse the evolution of the automotive industry in Brazil. The phase of strong protection for the local market ran from the time when assembly began in the 1950s until the late 1980s; this was followed by trade liberalisation, from the 1990s. These two phases are discussed in the rest of this section, which also addresses the special AR adopted by the Brazilian government between 1995 and 2000, in order to promote investment and exports.

### *2.1 Market protection*

Until the 1990s, thanks to strong protection, the Brazilian automobile industry almost exclusively targeted the local market. During this period, the automotive sector was composed of four foreign car assemblers: Ford, General Motors (GM), VW and Fiat; and four light commercial, bus and truck assemblers: Volvo, Scania, Daimler Benz and Toyota.<sup>3</sup> Car assemblers brought in vehicles that had been designed and introduced in other countries many years before; these products used to have a life cycle of about 15 years. All car assemblers relied on local engineering teams to adapt products developed abroad to specific local conditions such as bad road conditions and usage (which required more robust suspensions), climate differences (asking for changes in materials), ethanol fuel, lower consumer income (demanding cheaper components and less accessories), consumer tastes and so on.<sup>4</sup>

The strategy of manufacturing for the local market has not required significant technological activity. The share of engineers working in the assembly industry in Brazil in the industry total employment is an indicator supporting such argument. In the 1980s, it was less than 1% (Quadros, 1993). By the early 2000s, the share had quadrupled.

Major changes in the Brazilian automotive market and industry occurred in the early 1990s. These changes implied a significant redefinition in the local PD strategies of car assemblers. Two elements influenced these changes: trade liberalisation and government policies specifically focused on the automobile sector.

### *2.2 Trade liberalisation and growth in local demand*

The process of trade and investment liberalisation in the Brazilian economy started in the early 1990s, following the inauguration of the government of the first elected President after military rule. Brazilian assemblers were not prepared to face the competition of imported vehicles. The sudden explosion in vehicle imports intensified domestic competition and showed the need to update products and improve productivity and quality standards in local car and truck manufacturing. This has triggered an escalation in investment by assemblers. Total investment in the assembly industry in Brazil rose from US\$5.4 billion, in the 1980s, to US\$16.6 billion, in the 1990s, according to the Brazilian Automotive Industry Association (ANFAVEA). This figure comprises reinvestment by incumbents and inward foreign direct investment made by newcomers.

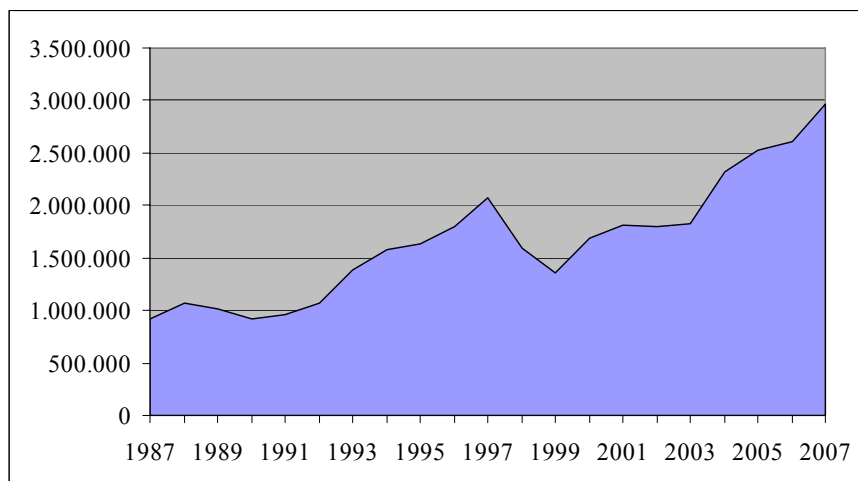
The largest share of such investment was made by assemblers already located in Brazil, either on modernising local assembly units and upgrading product portfolios, or on building greenfield assembly units. New entrants accounted for the rest. Toyota (vehicle division), Honda, Renault, PSA Peugeot-Citroën, VW Audi and Daimler Benz (vehicle division), along with light commercial assemblers like Chrysler (before the venture with Daimler Benz), Land Rover and Mitsubishi inaugurated new car plants

in Brazil between 1997 and 2002. VW inaugurated its own and independent truck and bus plant, in Resende, in 1996. Completing this cycle of investment was the arrival of Fiat Iveco and Navistar International, both assemblers of trucks.

Such investment was primarily market seeking. Brazilian domestic demand for auto vehicles rose steadily between 1991 and 1997, pulling the growth in output from approximately 1 million units, in 1991, to 2 million units, in 1997 (Figure 1). The relative saturation and stagnation of mature markets in industrialised countries contrasts with the recent dynamism of newly emerging economies: Brazil is one of the largest potential consumer markets in the world, with a population of about 175 million and a ratio of inhabitants per vehicle of around 8.8 (ANFAVEA). Moreover, given the actual and potential market, the scale of assemblers' operations in Brazil qualifies Brazilian subsidiaries to become the South American manufacturing basis.

After a set back in local demand, between 1998 and 2002, which was provoked by recession and the raise of interest rate following the steep devaluation of the Real in 1998, the internal market resumed steady expansion from 2003, reaching 2.5 million units, in 2007. In line with local demand, manufacturing output of the Brazilian auto industry rose from 1.8 million units, in 2003, to approximately 3 million units, in 2007. As output has come close to capacity (3.5 million units), assemblers increased investment again. According to vehicle manufacturers' own estimates, they are expected to invest R\$12 billion between 2007 and 2011. Large investment plans include those of Fiat (R\$3 billion in manufacturing from 2008 to 2010), VW (R\$2.5 billion from 2007 to 2011, in its five Brazilian manufacturing units), Ford (R\$2.2 billion up to 2011 including its purchase of Troller, a Brazilian manufacturer of off-road vehicles) and GM (US\$1 billion from 2008 to 2010). Hyundai of South Korea has also announced investments of R\$1.2 billion up to 2010. Smaller investments include Renault (US\$300 million in manufacturing and the development of a new design and engineering facility) and Nissan (US\$150 million up to 2009) (KPGM, 2007).<sup>5</sup> Cumulative investment for the period 1994–2006 was US\$35 billion (ANFAVEA, 2007).

**Figure 1** Brazil – 1987/2007 – automotive industry manufacturing output (vehicle units)  
(see online version for colours)



Source: ANFAVEA

### *2.3 Rising exports after 2002*

Relocation of manufacturing is another driver of FDI flows into Brazil. In spite of the historical peak in output and internal sales in 2007, local demand for autos and trucks in Brazil has been less than expected during the investment boom in the 1990s. Demand stagnated at an average of 1.6 million units per year (from 1998 to 2005). An unexpected development, accounting for the difference between output and local demand, was the substantial growth in exports. It is argued in the following section that such export growth is closely related to the increase in PD capabilities of the local subsidiaries of global assemblers.

In 1997–2002, an average of 20% of vehicles manufactured in Brazil was exported, roughly the same proportion as in the 1980s. In the 3 years after 2002, this figure rose to 35%, peaking at 897,000 units in 2005. Transport equipment (auto vehicles plus aircrafts) remains Brazil's largest export sector. The value of exports of auto vehicles, in 2005, at US\$11 billion, was 14% of the exports of manufactured goods. But, since 2006, the Brazilian exports of auto vehicles decreased, mainly because of the substantial appreciation of the real against the US dollar. As compared to the peak, the number of vehicles exported in 2007 reduced by 13%. In value terms, exports remain relatively stable: ANFAVEA forecasts a total value of auto exports of US\$12.1 billion in 2007 (KPGM, 2007).

The fact that Brazilian subsidiaries are well positioned to explore both other Latin American (LA) markets (including Argentina and Mexico) and African/Asian markets has been a driver for investing in Brazil and has contributed to the growth in exports. As a consequence, exports to China and the Middle East countries have grown substantially, because the Brazilian automotive industry has achieved economies of scale in the manufacturing of compact cars, on one hand, and trucks and buses, on the other hand. It has also developed a considerable knowledge of the particularities of such markets and accumulated capabilities for adapting and designing cars and trucks suited to them. However, some car models are also produced in variants which meet European regulations. In 2006, the composition of destination of Brazilian exports of auto vehicles (in units) was, in order of size, South America (47%), Mexico (23%), EU (9%), Africa (13.5%), Asia (6.5%) and other regions (1%).

PD strategies, especially among the four long-established players, have been greatly influenced by the new phase in the domestic automotive market, characterised by fiercer competition as well as a deep restructuring process. Trade and investment liberalisation have contributed to the integration of Brazilian subsidiaries of assemblers into their parents' global strategies.

### *2.4 Increasing new platforms in the 1990s*

The number of new car platforms (22) launched and manufactured in Brazil in the 1990s was more than three times the number in the 1980s. Most new platforms were launched in Brazil either simultaneously or even before they were launched in other countries. This helped to keep product portfolios updated and to narrow the gap between local and global product portfolios. The same applies to innovations in manufacturing processes and organisational techniques. Overall, the new product strategies have replaced the launching of vehicles based on or derived from obsolete platforms, which had been the

case for decades. More recently, some subsidiaries in Brazil (GM and VW) have assumed the design of entirely new car models (complete derivatives, according to Consoni and Quadros (2006) typology), both for the local and the external markets.

It is important to emphasise that the increase and upgrading in PD competences among automakers has had major implications for exports. As design centres for small car models, Brazilian subsidiaries have been in a good position to export to developing and developed countries, where these models are not manufactured. In the case of GM, the export of engineering services to other subsidiaries has been significant. Moreover, as the central site of PD projects for small cars, Brazilian subsidiaries can choose suppliers, increasing the likelihood that suppliers located in Brazil will become major suppliers to such models and will also export.

A similar development has occurred in the case of the Brazilian VW-TB division. As the major business and design centre for VW commercial vehicles in the world, the Brazilian truck and bus division has had to develop its own product and value chain organisation strategies. In terms of product design, VW-TB has focussed on the development of trucks and bus chassis which were more suited to the needs of emerging markets (robustness, simplicity and economic operation). This has required the building of product and process design capabilities, which will be discussed in the next section. The result was the global launch of three distinctive product lines for trucks plus one bus line, each line with many variations of load capacity. The design projects have been carried out in the VW-TB Global Design Centre, located in Resende, State of Rio de Janeiro. The focus on emerging market needs and the building up of PD capabilities in order to match those needs have contributed to the significant growth and market success of the relatively new VW-TB.<sup>6</sup> In 2007, it has become one of the largest Brazilian players<sup>7</sup> in the truck and bus market, achieving the first position in Brazilian exports of commercial vehicles and producing the best-seller truck in the country.

### **3 Policies for the automotive industry in Brazil**

Although the size of the Brazilian car market was one of the main factors behind the wave of investment in the 1990s, the importance of Brazilian government policies focusing on this sector, specifically the AR,<sup>8</sup> should not be underestimated as an additional incentive in the process of attracting new vehicle assemblers. The policy, implemented in 1996–2000, introduced a series of incentives for exports and for investment in new plants in Brazil (Quadros et al., 2000).

The first policy initiative, in the 1990s, was the organisation of the Sectoral Chamber for the Automotive Industry, between 1992 and 1994, which brought the Brazilian government, assemblers, suppliers, dealers and unions together to discuss automobile sector problems and led to the definition of policies specifically oriented to increase/sustain local consumer demand. The outcome was an agreement to reduce consumer taxes and vehicle prices, to increase local demand and output and maintain the level of employment. One of the most important measures adopted during that period was the zero Industrialised Product Tax (IPI) on vehicles powered by engines of up to 1000 cc. This has given birth to the ‘popular car’, a concept defined by low price, low-powered cars, with no optional items. Following this, popular car sales became the spearhead of the growth in demand for vehicles in Brazil. The market share of popular vehicles raised from 4.3%, in 1990, to 50%, in 1996. The wave of new plants, new car

platforms and new entrants – and acquisitions – resulting from AR increased the already dominant role played by TNCs, while leading to upgrading in terms of productivity, competitiveness and technological capability. However, as a signatory of the Trade-Related Investment Measures (TRIMs) agreement under the WTO, the government had to abandon this regime from 2000.

The AR raised the IPI for popular cars from 0% to 10%. For vehicles above 1000 cc it was kept at 25%, which helped maintain prices of the popular car competitive – price being critical for the Brazilian consumer. As a consequence, popular car sales continued to grow and, in 2001, they accounted for 75% of the domestic vehicle market. This allowed assemblers and suppliers to attain high scale of production – and created an industry bias towards specialising in the subcompact platform. In September 2002, the IPI rate was modified again, narrowing the gap between vehicles powered by 1000 cc engines and vehicles with engines above 1000 cc. Since then, the share of 1000 cc powered cars in Brazil has fallen steadily, to reach 59%, in 2006.

The incentive of lower IPI rates to boost the demand for low-powered subcompact cars has never been consensus among car assembler subsidiaries in Brazil, whose attitude has been formed by their product mix. Some assemblers have wished to keep the IPI incentive for popular subcompacts. Fiat, for example, has recently had the largest market share in Brazil (Table 1), which is largely based in its leading position in sales of popular cars. On the other hand, assemblers like GM, with more diversified product portfolio and sales, have favoured lowering taxation, to a lesser extent, for all sizes of vehicles.

**Table 1** Brazil automotive industry – brand market shares in the car segment (2007)

<i>Car assemblers</i>	<i>Market share (%)</i>
Fiat	25.9
VW	22.9
GM	21.3
Ford	10.4
Honda	3.7
Toyota	3.1
Others (Renault, PSA, Nissan, etc.)	12.6

*Source:* ANFAVEA (2007)

The popular car policy promoted both a recovery in the domestic consumer market and the specialisation of the Brazilian automotive industry in subcompact platforms. In spite of the relative reduction in the share of low-powered cars in the Brazilian market, specialisation in designing and manufacturing small cars has had important implications, as it helped increase output scale and improve PD activities and internal capabilities.

In order to conclude this section on the policy and institutional context, a word is necessary on the implications of the ‘fiscal war’ between Brazilian subregional entities, that is, states and municipalities, in order to attract investment to new automotive plants. The location of automotive manufacturing in Brazil has changed substantially in the 1990s and 2000s. Until the early 1990s, 85% of output capacity in vehicle assembly was concentrated in the State of São Paulo, and particularly in the metropolitan area of São Paulo city (Quadros et al., 1997). The State of Minas Gerais, site of Fiat’s plants and those of some of its suppliers, accounted for the balance. But of the nearly 1 million units of additional production capacity installed as consequence of investment in

1996–2001, approximately 75% were in states with little or no previous experience with assembly plants: Rio Grande do Sul, Paraná, Rio de Janeiro, Goiás and Bahia (Quadros et al., 2000).

Decentralisation of assembly plants in the automotive industry is not specific to Brazil and is related to factors such as labour costs and flexibility. But it is the case that various states and municipalities engaged in bidding wars used incentives favouring FDI, particularly in the period 1996–2001. They offered a range of incentives, comprising tax rebates, subsidised financing, free land for the building of new plants and public investment in urban and transportation infrastructure. Authors such as Rodriguez-Pose and Arbix (2000) suggest “the recent decentralisation of the Brazilian motor industry is basically linked to perverse territorial competition among Brazilian states” (p.1).

#### **4 R&D and technological capabilities in the Brazilian automotive industry: recent indicators**

As discussed above, since the mid-1990s assemblers in Brazil have invested in increasing local PD capabilities to meet the fiercer competition brought about by imports and, subsequently, to sustain exports. Indeed, Brazilian subsidiaries of multinational assemblers and suppliers have been enlarging R&D mandates in Brazil and stepping-up their product-related technological activities. As much as in other business areas, these changes in Brazil are also due to an important change brought about by the globalisation of the automotive industry. This is the increasing internationalisation of R&D, based on design specialisation of subsidiaries, and its integration in a global, networked organisation. This process has already gone beyond the Triad countries (USA, Europe and Japan) and reached some developing economies like Brazil, India and China.

Results from the three rounds of the Brazilian Innovation Survey (PINTEC-IBGE) lend empirical support to such observations. The surveys refer to years 2000, 2003 and 2005. Data show that, relative to the entire Brazilian manufacturing industry, investment in total R&D by the automobile industry (including automakers and auto-parts suppliers) has increased substantially more. The auto industry spending on R&D grew 250%, from R\$549 million, in 2000, to R\$1.9 billion, in 2005 (approximately US\$900 million) (Table 2). R&D spending by the Brazilian manufacturing industry as a whole grew 85% in the same period. In 2005, technological intensity, that is, the ratio of R&D expenses to net sales in the automotive industry was 1.4% (up from 1% in 2000), whereas the average ratio for the manufacturing industry was 0.7%. Such numbers are the result of the expansion of PD units in the incumbent assemblers, as already mentioned, and, to a lesser extent, in component suppliers. As will be further explored in this paper, R&D activity in this industry refers primarily to product and process development (D rather than R). Yet, such change also reflected in the importance of the automotive R&D activity in Brazil. The share of the auto industry R&D spending in total industrial R&D spending, in Brazil, doubled from 2000 to 2003, reaching the level of one quarter of the total business firm R&D investment in the manufacturing industry (Table 2). It is important to add that assemblers account for 80% of the spending on R&D.

**Table 2** Total R&D spending<sup>a</sup> by the Brazilian automobile and manufacturing industry (2000, 2003 and 2005)

	2000	2003	2005
<i>Automotive industry</i>			
Total R&D (R\$ million)	549	1.363	1.900
Total R&D/sales (%)	1.0	1.6	1.4
<i>Manufacturing industry</i>			
Total R&D (R\$ million)	4.336	5.739	7.979
Total R&D/sales (%)	0.8	0.6	0.7
R&D auto/R&D total industry (%)	13	26	24

Source: PINTEC/IBGE (Brazilian Innovation Survey)

<sup>a</sup>Total R&D spending comprises external R&D and outsourced R&D.

#### 4.1 *Rising numbers of engineers*

In line with the increase in R&D expenses, the number of engineers in the Brazilian auto assembly industry jumped from 2110 professionals or 2% of total assemblers' employment in 1993, to 3544 professionals (4.3%) in 2001, while the average share of engineers in the labour force in the entire manufacturing industry was steady at 0.7%.

Technological trajectories and strategies in the automotive industry help explain the increase in R&D expenses. Until the late 1990s, product-related technological activities developed by automakers in Brazil had been concentrated mainly on nationalisation and platform adaptations to local conditions (tropicalisation) and, to a lesser extent, on the development of local models, or derivative vehicles, from global platforms to suit local demand requirements. After the 1990s, some assemblers went beyond this level by accumulating capabilities in designing and engineering Complete Derivative Vehicles (Consoni, 2004).

At the level of the individual firm, trajectories have varied considerably and evolved rather hesitantly. Some assemblers have adopted centralised product strategies, in which technological activities have been developed at headquarters or at subsidiaries located in developed countries. But the experience of other assembler subsidiaries and their accumulated design competencies suggest that they are becoming partners to their headquarters in global PD subcontracting. Such decentralised product strategy has been associated with product policies that are oriented towards local and regional market needs. The strategy is based on a concept of organisation in which the PD functions of assemblers (and some of their suppliers) are dispersed and keep a certain degree of autonomy. This has gone furthest in the case of VW-TB, as the Brazilian operation for trucks and buses has become one of the major locations for design, marketing and manufacturing, with autonomy to define marketing and product design strategies for emerging markets.

## 5 **Product development competencies in assemblers in Brazil**

Vehicle assembler subsidiaries in Brazil have adopted different paths to the globalisation of products and PD. These can be divided into centralising and decentralising. Each strategy has different impacts on local product policies adopted by vehicle assemblers outside their home-based country as well as distinctive implications for the development of local innovation capabilities.

Product design centralised strategy implies a single global product policy, in which the most significant activities of PD (platform and its derivatives) are centralised by TNCs (mostly in their headquarters), with little being carried out in Brazil. This means that car assembler subsidiaries tend to adapt vehicles to local markets with little creation and use of new knowledge, promoting only minor changes in the final product. As a consequence, local adaptations as well as local technological activities tend to be minimised. Product decentralised strategy has been associated with product policies more oriented to local/regional market needs. It implies an organisation of PD in which the main functions of vehicle assemblers are structured according to regional divisions, which are interrelated but have a certain degree of autonomy. The decentralised policy contributes to increasing local engineering staff and upgrading local technological activities and competencies.

In contrast to the Indonesian case, where most vehicle adaptation activities are carried out abroad under (Japanese) assemblers' headquarters coordination (Sugiyama and Fujimoto, 2000), a different tendency is observed in Brazil. Empirical work did not find a unique product strategy among Brazilian subsidiaries of vehicle assemblers. Instead, assembly subsidiaries have adopted different product strategies, choosing between centralised/decentralised, depending on decisions from headquarters and the capabilities accumulated in the subsidiary.

### *5.1 Newcomers' centralised strategy*

There are some similarities between product strategies adopted by the newcomers, like Toyota, Honda, PSA Peugeot-Citroën and Renault. All have launched products in the Brazilian market that have not only been conceptualised and designed for mature markets, but whose reengineering (adaptation to local technical and taste conditions) has been carried out abroad (either in Europe or in the USA). These findings confirm the findings in previous research, on Renault and Honda, in 1998 (Quadros et al., 2000). The main reason behind extreme centralisation of PD and product policies is the low scale of their operations in the new market. These car assemblers have moved into Brazil recently and, due to their lower local output and sales volume (in comparison with traditional players), the Brazilian operation cannot support local technological activities and PD. In 2007, the output of newcomer assemblers represented 11% of total output in the Brazilian automotive industry and their domestic sales (including nationally manufactured and imported vehicles) represented roughly less than 13%.

The activities of these car assemblers are mostly oriented to small adaptations in product or process, to nationalisation of components and mainly to technical contact with their local suppliers.<sup>9</sup> For instance, Toyota has tried to harmonise the supply of Brazilian auto parts according to Japanese standards while Renault has tried to adapt to Brazilian auto parts and local materials, which are very different from French ones. For more complex technological activities, these TNCs have counted on their major R&D centres abroad. The same applies to adaptation required in the local manufacturing process, in general related to reducing the use of automated technologies in the original process projects, due to the fact that Brazilian plants operate at much lower output volumes.

Headquarters must approve any significant product modification, involving more complex technological adaptation. Thus, it is clear that these TNCs' affiliates in Brazil are subject to a lower degree of autonomy in comparison with their more established competitors. In spite of such limits regarding decisions on products and technological

activities, Brazilian subsidiaries of newcomers have been given the role of centre of manufacturing and sales for LA countries. Brazilian units have been responsible for the coordination of their regional activities, especially when there is more than one plant. Moreover, the responsibility of Brazilian units includes technical support to other LA units.

To summarise the findings for this group (newcomers), Toyota, Honda, PSA and Renault have strongly pursued centralised product strategies in Brazil. The vehicles they have launched in Brazil were developed in their headquarters, going through only small adaptations to Brazilian conditions, adaptations that have also been engineered abroad. However, recent developments suggest that this picture may change in the near future, at least in the case of the French assemblers. Renault has launched a new global model (the Sendero), which is based on the Logan platform and takes into account the requirements and tastes of Mercosur and other emerging markets. The Sendero design project had the participation of Brazilian engineers, in the America Engineering Centre, inaugurated in 2006, in São José dos Pinhais, State of Paraná. The PD unit has a branch in Argentina and is focused on the adaptation of global products and the design of products focused on the LA market (and based on global platforms). It is planned that the engineering staff of the Centre will employ 740 engineers and technicians by 2009, 75% out of which located in Brazil. In 2006, the product and process engineering workforce employed 360 engineers and technicians. PSA/Citroen announced, in late 2007, that a decision had been taken to establish a global PD unit in the City of São Paulo, in the next 2 years. PSA/Citroen has planned to hire a PD workforce of 1000 engineers.

## *5.2 Evolution of the major incumbents' trajectories*

In contrast, product strategies adopted by the major car assemblers established for some time in Brazil (VW, GM, Fiat and Ford) have been much less centralised. These corporations have been manufacturing and assembling cars in Brazil since the 1950s,<sup>10</sup> and have kept a relatively stable and strong position in the Brazilian car market. As seen before, in 2007 they accounted for approximately 80% of the domestic vehicle market in Brazil (Table 1). In the phase of import substitution industrialisation and protected internal market, these assemblers built autonomous areas of product engineering for designing and developing products specifically focused on the local market, often adapted from old models from Europe and North America. Domestic sales volume was enough as to maintain these activities in Brazil, although at a level of technological advance considerably lower than that of Triad counterparts.

However, with trade liberalisation and the closer integration into global strategies required by parent companies such subsidiaries have substantially changed their product and PD strategies in Brazil. They have redefined the way their products are conceptualised, designed and engineered, in the sense that assemblers sought cost rationalisation through eliminating asset and task duplication, particularly regarding technological facilities and engineering staff. This move has had significant implications for the organisation of local engineering activities. The incumbent Brazilian vehicle assemblers have divided into two contrasting groups. While from the beginning of this phase, Fiat and GM have pursued a rather decentralised product strategy, VW and Ford (the latter more clearly) initially (in the late 1990s) pursued a centralised strategy, which was subject to major revision in the early 2000s.

### 5.3 *Decentralisation at GM and Fiat*

Since 1995/1996, GM and Fiat have been inclined to adopt decentralised strategies. Both have built local autonomous engineering centres with the capability to participate in global platform projects, provide inputs related to local requirements as well to design regional derivatives to suit local preferences. 'Global thinking but local doing' seems to describe their local product strategies, which can be termed product 'globalisation' (Quadros and Queiroz, 2001). However, GM has invested substantially more than Fiat in localising PD and engineering activities in Brazil. The latter has adopted a consistent and pioneering product policy by designing global cars for emerging markets, but the technological effort required by such policy remained largely centred in Italy (though with the participation of Brazilian engineers), until recently.

GM do Brazil (GMB) is the most clear-cut example of the decentralising path. In the 1990s, GMB accumulated local technological competences based on the design of regional derivatives such as the Corsa Sedan and pickup and the Astra Sedan. The combination of capabilities and technical infrastructure in the GM Brazilian subsidiary together with the volume of popular car sales in the domestic market created the preconditions for the development of the Blue Macaw project. This project gave birth to the Celta model, a subcompact car derived from the Corsa platform, with substantial modifications and redesign. The Celta project entailed two major advances for the local unit of GM. First, GM Brazil, especially its engineering team, played a major role during all PD stages of the Blue Macaw project. Thus, the Celta vehicle was specifically planned and designed for the Brazilian market and GM Brazil coordinated all the development process. Second, it promoted major innovations in car manufacturing process organisation, by introducing the concept of 'industrial condominium' for the first time into GM Corporation (GMC). This concept is defined by a compact and modular plant where the assembly line is segmented into modules operated by suppliers. Suppliers are installed inside the GM plant (at Gravataí, a greenfield site) and take responsibility for the whole development, delivery and assembly of modules or complete systems. Such responsibilities include the employment of direct workers, the development of tools and equipment and the control of the assembly logistics. The Blue Macaw project introduced e-commerce, as Celta was the first car model to be sold through the internet in Brazil.

These experiences and the capabilities accumulated have assured GMB a significant role in PD activities. This was reinforced in the process of conceptualising, developing and launching, in 2002, the minivan Meriva, which was also launched as a supermini in Europe. The case of Meriva has been considered a new phase in terms of PD, not only for GMB but also in the context of the Brazilian automobile industry. First, because it is a global concept and project proposed by the Brazilian subsidiary and later incorporated into GM's European product portfolio (inverting the knowledge flow, in this specific case). Second, because it was the first PD project located in the country that involved a thorough reengineering of the original platform (Corsa), including the original dimensions. All stages of development occurred under the GMB responsibility. According to Clark and Fujimoto's (1991) typology, these stages include conducting concept studies, building models, testing prototypes, solving problems in pilot plants and getting the car ready for commercial productions. Even though GMB had worked with Opel (the subsidiary of GM in Germany), coordination of the Meriva project was the responsibility of the Brazilian staff. The size of the Meriva project justified the allocation of an exclusive development team to this project, for the first time in Brazil.<sup>11</sup>

The technical and commercial success of the Meriva has qualified the Brazilian PD unit to become one of the five global PD centres, in the GMC restructuring of product design and engineering, in 2005. GMC has rationalised PD activities by concentrating PD in a network of five specialised global centres, which are located in the USA, Europe, Brazil, Korea and Australia. The Brazilian centre is in charge of the product design and engineering of medium-sized utility vehicles as well as of designing and/or adapting global platforms for the Latin America, Africa and Middle East (LAAM) markets. In spite of the fact that the Brazilian GM PD centre has lost the much aspired mandate for PD of subcompact platforms to Korea, the centre has increased its workforce and facilities since then. By 2007, the PD staff of the Brazilian centre was composed by a 1180 thousand engineering workforce, of which 40% postgraduates, and a support staff of 440 employees, distributed between the São Caetano Technological Centre and the Indaiatuba proving ground, both located in the State of São Paulo. Indaiatuba proving ground is considered GMC's third testing ground in terms of completeness and sophistication of labs, prototyping and proving facilities and GMB is expected to invest further in the proving ground in the next years.

Fiat is also an interesting case of a decentralised trajectory. Fiat Brazil has been engaged in designing derivatives from the the Uno platform. Another interesting example is related to the 178 Project, the Palio platform. This project was specifically designed for emerging markets, according to their specific needs and productive capabilities. Although the 178 Project was developed under the coordination of Fiat Italy, the Brazilian engineering team had an integrated role in the process, specifically in the final stage of development, during the design of its derivatives – sedan, wagon and pickup. Later, in the redesign of the Palio second generation, half the engineering workload was carried out by the Brazilian PD team (Dias, 2003) and the strategy contributed to the growth of the engineering staff and the upgrading of technological facilities at Fiat Brazil.

In terms of capability in project design, Fiat Brazil has been recognised as an excellence centre for hard suspension modules within Fiat Corporation. But the investment in labs and in the expansion of the PD engineering workforce has been quite limited, in the 1990s. However, the combination of local capability in PD and the attainment of sales leadership in the Brazilian automobile market has contributed to Fiat increasing technological activities in Brazil, from 2001. Fiat stepped up investment in labs, styling facilities and in the engineering workforce since then. The Betim Development Pole now comprises an electro-electronic lab, with one of few semi-anechoic chambers installed in Brazil. In 2008, Fiat will invest in building a crash-test lab. The styling centre is the only of Fiat Group outside Europe. In 2007, the PD workforce of Fiat Brazil comprised a 600 employees staff, out of which 380 were engineers.

#### *5.4 Evolution of Volkswagen's and Ford's trajectories*

A quite different situation was found in VW and Ford. The economic crisis in Brazil in the 1980s and the stagnation in domestic demand for cars led the VW and Ford subsidiaries in Brazil to merge into a cost cutting-oriented joint venture named Autolatina, in 1986. VW held 51% of the shares and Ford 49%. Autolatina was an *ad hoc* response to the crisis, aimed at increasing economies of scale and reducing fixed costs by sharing platforms and power trains. In 1994, trade liberalisation and the new pattern of competition brought the Autolatina arrangement to an end. Following this, both VW and Ford adopted substantial changes in their local product strategies.

Until the 1990s, VW do Brazil pursued a product strategy aimed at meeting the requirements of the internal market, with strong local engineering and technical facilities. VW was the most advanced carmaker in Brazil in terms of local technological activities, designing and developing products specifically for Brazilian conditions. Nevertheless, with the end of Autolatina VW do Brazil abandoned the strategy of developing products locally. At that time, this was in line with the VW headquarters' decision to adopt a global product strategy for its worldwide subsidiaries. This meant all vehicles launched in Brazil should be derived from a global project and adapted only to match most critical local technical requirements. So this was the case with the so-called P-24 platform project, in the late 1990s, which originated the Polo platform. However, the relative small penetration of the VW Polo in the LA market, which is related to its considerably higher cost as compared to other models in the compact car segment, has soon led VW to review the orthodox approach to the globalisation of PD.

In the early 2000s, VW do Brazil coordinated the development of a new product – the Fox – which is simpler and less costly than the original platform (the Polo) and thus more suited to emerging country markets, but which was also designed as an entry vehicle for European markets. The Fox is a derivative of the PQ 24 global platform. In addition, VW do Brazil accumulated considerable competence in developing small, efficient and cheap low-powered engines, incorporating the turbocharger technology. In line with such change in marketing strategy, VW decided to expand its engineering team. In contrast to the GM and Fiat cases, the Brazilian VW car PD unit, which is named Product Development and Engineering Department (PDED), has not a specialised global mandate, but is rather focused on adapting and creating derivatives for emerging markets. The Fox case, which is also a commercial success in Europe could suggest that this is not the case, but that VW has specialised the Brazilian subsidiary in the PD of subcompact global platforms. However, VW continues to keep the local subsidiary' PD capacity focused on derivatives for emerging markets. Still, VW do Brazil employs a relatively large PD staff. In 2006, PDED counted 1500 engineers, designers and support staff.

The clearest contrast to GM's and Fiat's strategies is that of Ford, which has taken the centralised product strategy further. During the period of market protection, Ford do Brazil accumulated the know-how to design local models. After the end of Autolatina in 1994, the Brazilian subsidiary was reintegrated into the global strategies of the Ford Corporation, namely the Ford 2000 Programme. As a result, Ford abandoned its local product strategy approach in Brazil and dismantled its product engineering effort there. Centralisation required that all the vehicles Ford launched in Brazil needed to be adapted to the USA or Europe (this was the cases for the Fiesta and Ka vehicles). But this has proved to be an expensive and inefficient strategy, as demonstrated by the Amazon project. The original plan was to centralise the whole project in Ford's UK technology centre, including the design of derivatives for emerging markets. Brazilian engineers were expected to participate marginally, providing inputs related to market requirements. However, it became clear that the differences between emerging market and European cost and technical requirements were so great that they could not be dealt with in a single project. The Amazon project split led to the transfer of responsibility for the Brazilian derivatives to Ford US, which subcontracted most of the job to engineering services suppliers (Quadros et al., 2000). The overall result was a major delay in the Brazilian launching of the new Fiesta and of a budget utility sport car built on the Fiesta platform (the EcoSport) As a consequence, Ford do Brazil underwent a period of further reduction in its market share, in the 1990s.

However, after recognising that the absence of local support for PD was behind Ford's continuous losses in the Brazilian market, Ford became determined to reverse this situation and reconstruct its Brazilian engineering effort. Information collected in interviews suggested that Ford do Brazil started hiring product engineers again, from the early 2000s as well as to invest in expanding technological infrastructure. Ford reported, in 2007, to employ 1200 engineers in PD, who are located partly in its PD units in Camaçari (cars) and partly in São Bernardo do Campo.

### 5.5 *The strategy and trajectory of Volkswagen Truck and Bus*

The evolution of the commercial and PD strategy of VW-TB reveals one of the most advanced cases of PD autonomy and building up of capabilities. Ironically, the same managerial leader<sup>12</sup> who has attempted to introduce the recentralisation of car platform development back to VW Germany has initiated, in the early 1990s, the seed of an innovative truck plant in Resende. To be sure, at that time Mr. Arriortúa's plans were innovative on the manufacturing process and sourcing side, rather than on the PD side. The Resende truck plant represented a twofold strategic move from the VW Group. First, it has inaugurated the first self-reliant and full truck operation at the VW Group in the world. Since the 1950s, VW has had a commercial vehicle division, which has been mostly dedicated to the design and manufacturing of vans and light commercial vehicles, of which the Transporter<sup>13</sup> used to be the major selling success. Yet, the core of VW's strategy for the truck European markets has been relying on joint ventures with the German MAN truck maker. From 1977 to 1993, the MAN-VW joint venture has manufactured a range of light, medium and heavy trucks under the brand MAN. The recent acquisition of a minor stake in MAN and the takeover of Scania by the VW Group show both, the interest of the group in the truck market and the intention of relying on other makers' competencies and brands, as far as the European and other developed country markets are concerned. However, as for developing country markets, VW took the opposite direction, since the end of the Autolatina joint venture with Ford in Brazil, in 1995. In 1996, VW started in Brazil, with the inauguration of the Resende plant, its first independent truck and bus operation, based on its own design, engineering and platforms. The truck and bus operation started as a division of the Brazilian subsidiary of VW and has been successful to the point of supporting the split of VW-TB division into a new and separated company, the VW commercial vehicles. The new company has headquarters in Hannover and the major plant and R&D unit located in Resende.

The second strategic move related to the Resende plant was the radical change in the concept of supply chain and industrial organisation introduced with the modular consortium. In the new plant, VW was in charge of product design and engineering, supply chain management, quality control and marketing and branding, while the seven risk sharing supply partners or *moduleiros*, which have shared the plant investment with VW, were in charge of industrial operations and the logistic of the supply chain. VW took advantage of the inherently modular nature of trucks in order to 'modularise' the plant itself. The plant layout is organised into modular units,<sup>14</sup> each of them managed and operated by one *moduleiro*. Thus, at the Resende plant the suppliers of modules assemble not only the modules, but the final product itself under the VW roof. Beyond a process innovation, the modular consortium introduces a new business model in the truck business.

The location of the truck operation in a developing country market has been important to align PD (and respective capabilities) to the requirements of such market type. In the first generation of products (the VW worker truck line), VW itself was in charge of design and engineering activities, relying mostly in its own resources and buying engineering and design capability from automotive engineering firms, mostly in Europe. For the second generation of trucks, the more sophisticated Constellation line, VW combined its own R&D in Brazil, with external engineering services and suppliers engineering capability. Thus, the modular consortium has evolved from a purely industrial operation partnership towards a co-development partnership, contributing to increase Brazilian suppliers' PD capabilities.<sup>15</sup> The market performance of VW-TB in Brazil suggests that such strategy presents critical competitive strengths. VW trucks' market share has increased, since the beginning of its operations, up to near 30% of the Brazilian market of commercial vehicles, representing a threat to the market leader (Daimler). On top of presenting model alternatives which incorporate less electronics, a feature that can be convenient for transport operators, particularly in the less developed areas in developing countries, VW maintains a B2B centre in Resende, oriented to customising products to large clients' needs. VW trucks made in Brazil have also been doing well in export markets of Latin America, Africa and the Middle East. Export penetration and the valuation of the Brazilian currency have contributed to the decision of building new truck plants in Mexico (2003) and South Africa (2005), which assembly CKD trucks exported from Brazil.

The success the VW-TB division in Brazil has reflected in the consolidation of the Global Development Centre for trucks, in Resende. The centre is in charge of leading the product engineering activities and projects aimed at new platforms and models. The local PD team comprises approximately 200 engineers and 100 technicians. The centre continues to rely on support from VW Germany, particularly as regards cabin design and certain laboratory services. EDAG do Brazil, a major engineering services provider in the automotive industry, also complements the Resende engineering capacity.

### *5.6 Product development competencies in assemblers in Brazil*

Summarising the findings above, on the one hand, there are cases of assemblers which have relied almost exclusively on technological activities developed abroad, thus following a completely centralised product strategy. This has been the case of the assemblers installed in Brazil in the late 1990s (Renault, PSA, Toyota, Honda and DaimlerChrysler), although the French makers have recently started to change this approach. In the case of the Japanese assemblers, the scale of operations in Brazil is small (compared with the major players) and there is no evidence that they will follow a more decentralised product strategy in the near future.

On the other hand, the recent experience of some of the major assembler subsidiaries (GM, VW, Fiat, Ford), and their accumulated design competences, suggest the possibility that they are becoming partners to their headquarters in global PD. Because the Brazilian market specialises in subcompact cars, these assemblers have developed competence in the design of small and efficient engines (up to 1000 cc). Some have developed competence in developing suspension modules and all of them accumulate competence in power train that runs with alternative fuels (only ethanol or a mixture of ethanol and gas GM and VW are the most significant cases). They have adopted decentralised

product strategies, although following the global platform concept. Moreover, their local R&D activities have developed in scope and range and they have been strongly engaged in designing regional derivatives from global platforms. But although eventually GM's and VW's strategies converged in the 2000s, they followed distinct strategies in the second half of the 1990s. While GM quickly adopted a decentralised PD strategy, VW tried to follow a centralised one. The difficulties of the German assembler with the selling of the Polo in Brazil, and consequent loss of market share, eventually led VW to review its approach. However, as regards the truck and bus operation, VW has adopted the most decentralised strategy within the VW Group, as the Brazilian operation has become the centre of the truck operation of the group for developing country markets. The strategy adopted by GM and VW has implied an enlargement of Brazilian engineering capabilities, increasing technical staff and improving local technological facilities.

The research on which this paper is based has revealed that PD capabilities can be organised in five progressive stages with increasing levels of complexity.<sup>16</sup> Individual assemblers have reached different levels of complexity, across such classification of stages, from basic, to incremental, to innovative capabilities. The five stages of technological capability (according to complexity) can be grouped into three levels of capabilities.

First, at the bottom of the classification, the nationalisation stage corresponds to the basic capabilities level, necessary to operate in the country. This simplest level of PD capability is related to the nationalisation of parts and components. This is a routine skill, which any carmaker operating in the country must develop and refers to being able to search for, select and contract local suppliers to produce parts and components in order to reduce dependency on imports. Engineering competences here have to do with evaluating suppliers and keeping links between such suppliers and manufactures abroad. Most of the newcomers, with small operations in Brazil, have not gone beyond this basic level, since even their tropicalisation activities have been carried out in their headquarters.

The second level of capability – Incremental Innovative Capabilities – involves the capability to improve, change or create products, which need more complex activities and demand more sophisticated engineering knowledge. This capability type comprehends three stages of intermediate PD capabilities – Tropicalisation, Partial Derivative Projects and Complete Derivative Projects – which are characterised by cumulative and more dynamic and complex technological knowledge.

Tropicalisation refers to the capability to adapt existing platforms and derivative models to the specific requirements of the local market or of local production. This comprehends a wide range of issues, from the use of alternative fuels (ethanol) or variations of gasoline composition, to the adaptation of suspension to bad road conditions and to the search of cheaper or more adequate materials. Particularities in consumer taste, which may affect design, are also included here. All incumbent assemblers have developed a strong basis in such competences, which has given them considerable competitive advantage over newcomers.

In this regard, the most important developing market in Brazil is the one for alternative fuels, related infrastructure and 'flex-fuel' autos that can use either ethanol or gasoline, or a mixture of both. Flex-fuel vehicles appeared on the market in the early 2000s and by 2006 had established a commanding market share. Fiat, Ford, GM,

Peugeot, Renault and VW all have flex-fuel development and manufacturing centres in Brazil. KPMG in Brazil forecasts that flex-fuel vehicles will account for three quarters of the Brazilian market by 2010 (KPGM, 2007).

The following level – Partial Derivative Projects – corresponds to more recently developed capabilities, mostly after trade liberalisation in the 1990s. It refers to the technological competences necessary to design partial derivatives from global platforms and global models. A typical example is the development of notch (sedan), wagon and pickup versions from hatch platforms, as recently GMB has done from the Corsa platform (Montana pick-up) and VW from Polo platform (Polo Sedan). Although with the close technical involvement of the parent's PD centre in Italy, Fiat Brazil has done something similar with the Palio platform (the Siena), as has Ford from the Fiesta platform (Fiesta Sedan). However, Fiat and Ford have not gone beyond this level.

The fourth level refers to the capability to design and engineer Complete Derivative Platforms. This involves the competences required for the development of entirely new models from existing platforms, sometimes requiring extensive reengineering of platform dimensions and new base knowledge for new product design. Only GMB and VW have reached this level, with the development of the Meriva (GMB) and the Fox (VW). Such completely new derivatives are global products, developed in Brazil not only for South American but also for European markets.

Although such PD competencies classification seems to be linear, it does not imply that the accumulation and upgrading of technological capabilities among Brazilian assemblers has followed a linear and unique trajectory, without difficulties or problems. As mentioned before, the recent history of VW do Brazil and Ford Brazil shows the opposite of a linear trajectory. The role played by the subsidiary in corporate global strategies has an important impact on both the levels of technological capabilities attained and on new world product mandates gained.

Advanced innovative capabilities have not yet been developed among car Brazilian assemblers. This refers to the most complex technological level at the top of the classification and corresponds to the stage of platform development and related R&D. Platform development implies the design of a complete platform and its derivative versions by the Brazilian subsidiary. The reason for the absence of this level is more related to TNCs' global strategies and the role assigned to Brazilian car assembly subsidiaries in such strategies, than to the absence of technological capabilities for designing entirely new products. Some assemblers have already consolidated the base knowledge for designing a complete platform in Brazil, particularly for the compact and low-cost car segment, but do not have a world mandate for designing a new global platform, following Birkinshaw's definition.<sup>17</sup>

According to such definition, however, the case of VW-TB could be included at the level of advanced innovative capabilities in terms of PD. Indeed, VW-TB in Brazil has the mandate to develop, produce and marketing VW-TB in all developing country markets and has performed accordingly. Yet, one has to be cautious as regards the use of such classification, as the level of complexity in truck development, as a modular product, may be lesser than that involved in car development. While the authors do not have a clear response to this question so far, it is recommended that car PD capability levels and truck PD capability levels should not be mixed.

## 6 Conclusions and policy implications

The product policies and technological strategies of the Brazilian subsidiaries of assembler TNCs have played an important role in the building of PD capabilities and the upgrading of automotive engineering in Brazil. This is particularly true in the case of the strategies pursued by the leading players in the Brazilian automotive industry: GMB, VWB, Fiat do Brazil and Ford do Brazil. Yet different TNCs have followed distinctive technology strategies, ranging from very decentralised to centralised.

The Japanese producers, whose output in Brazil is considerably less than that of the long-established assemblers, keep PD and technological activities centralised in PD centres abroad (mostly in headquarters), even as regards the basic adaptation of products to the Brazilian market. Thus, their affiliates have not gone beyond the basic PD capabilities for nationalising parts and components. Moreover, even the leading, long-established players have not followed a straightforward trajectory towards adoption of decentralised PD strategies. GM has invested substantially more than Fiat in localising PD and engineering activities in Brazil, which explains why GMB is ahead of the Italian maker in terms of local accumulation of technological capabilities. On the other hand, VW and Ford first followed a recentralisation strategy, suspending investment in local engineering and technological facilities in the second half of the 1990s. The concept behind this move was of truly global products (one basic design for all markets, either in developed or developing countries), which would allow for economies of scale in PD at the headquarters level. Falling shares of the Brazilian automotive market showed such players that the global car policy had been outperformed by regional car policies based on global platforms. Thus, in the 2000s, VW and Ford reversed their product and PD strategies, resuming investment in local engineering capabilities. As VW do Brazil already had considerably larger engineering capabilities and facilities in Brazil, it has been easier for the German maker to reverse and resume the accumulation of PD capabilities. Ford's situation was more difficult to change, as it had substantially reduced and downgraded its engineering department in the 1990s. This is why VW do Brazil is ahead of Ford do Brazil in terms of PD capabilities.

### 6.1 *Benefits of decentralisation*

Significant benefits for Brazil have accrued from the decentralisation of PD activities adopted by leading assemblers. The most direct and evident is the increase in local technological capabilities. An indicator of such direct development of competencies is the number of engineers dedicated to product and process development. The two affiliates that have progressed to the upper stage of PD competencies – GM and VW – are the ones with the largest staff employed in product and process engineering.

Another important aspect is the indirect effect on technological capability accumulation in suppliers. Increasing PD activity in assembler subsidiaries has entailed a similar process in the Brazilian global supplier subsidiaries. In fact, a large proportion of the technical effort demanded by tropicalisation and the design of regional (and global) derivatives has been performed by multinational, rather than national, suppliers of auto parts in Brazil. Global suppliers like Eaton and Bosch have advanced in the process of regional specialisation of Brazilian subsidiaries, by raising them to the status of global centres of excellence for certain types of components. For instance, as regards starter electrical engines, the Brazilian subsidiary of Bosch was given the global mandate for the

design and manufacturing of starters applicable to vehicles up to 1600 cc. Moreover, global assemblers and suppliers of systems, like Bosch, have already adopted policies aimed at involving local suppliers in PD (Quintão, 2008).

Upgrading in manufactured goods exports is another benefit from decentralisation in PD and the accumulation of PD competencies. As discussed, growth in exports of vehicles, manufacturing specialisation and increasing local R&D activity are tendencies that have reinforced each other in the Brazilian auto industry. In 2004 and 2005, Brazil attained significant levels of exports in automotive products.

It is notable that such economic and technological achievements have been attained so far without significant government intervention or support, except for the adoption of the AR between 1995 and 2000. But this may not be sustainable. India and China have designed policies to attract R&D investment from TNCs (United Nations Conference on Trade and Development (UNCTAD), 2004). If they succeed in attracting automakers' R&D, this might undermine the trajectory Brazil has undergone so far, in which case the virtuous cycle – PD activity/manufacturing specialisation/exports growth – might be diverted to Asia. Hence, it is important that industrial policies clearly identify the role played by leading players and the preferred form of linkages to them. Producers need to be made aware of the consequences of different strategies followed by different TNCs in the automobiles value chain. Policies in this area are not just related to fiscal incentives, but rather to the provision of science and technology infrastructure and a robust policy for the supply of highly skilled human resources. Policies to support local learning and the technological upgrading of local suppliers are also required.

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## Notes

- 1 The category 'vehicle platform' usually comprise the major underbody systems of a car. However, it may comprise different systems between distinct assemblers (Sturgeon and Florida, 2000). According to Yusuf et al. (2004), "as the number of production locations multiplied during the 1990s, automakers sought to streamline operations on a global scale, particularly in the area of vehicle design and component sourcing. Most automakers today are seeking to place a greater number of car models on fewer underbody platforms, allowing for greater commonalization and reusability of parts, while retaining the ability to adapt specific models to local tastes and driving conditions".

- 2 The doctoral research carried out by Consoni (2004) focused on car passenger assemblers (carmakers) in Brazil. The research carried out by Quadros, in a joint project with the Institute of Development Studies, Sussex University, UK, and the University of Marburg, Germany, focuses on German assemblers of cars and trucks, as it is part of an international study comparing the strategies of firms in Brazil and Germany and their spillover effects.
- 3 To be sure, the brands Ford, GM and VW also produced trucks and light commercial vehicles at that time.
- 4 Although most vehicles produced in Brazil were adaptations of designs developed in Europe, there were some exceptions. In the 1980s, VW designed the BX Family, which was the platform of the model Gol (subcompact passenger car) and its derivatives. This was designed in the Brazilian unit of VW, under the local engineering team. The Gol has been the most popular vehicle in Brazil for many years.
- 5 KPGM (2007) *Automotive Momentum – Brazil, Industrial Markets*.
- 6 The Resende plant which is the core of VW-TB operations was inaugurated in 1996.
- 7 Daimler is the other major player, both in terms of total market share and exports. Yet, Daimler's operations as manufacturer in Brazil (under the brand Mercedes Benz) date back to the 1950s.
- 8 Mexico and Argentina adopted similar regimes.
- 9 The exception was the design of the sedan derivative of Renault Clio, in order to compete in this market segment.
- 10 Except for Fiat, whose manufacturing operations in Brazil started in the 1970s.
- 11 For more details about Meriva development stages and the implications for the GMB technological capabilities, see Consoni and Quadros (2006).
- 12 José Ignacio López de Arriortúa.
- 13 The van Transporter was the first vehicle model to get off the assembly line of the VW Brazilian plant, in 1957. The renamed Kombi is still manufactured in Brazil, on a very old-fashioned manufacturing process. In spite of its dated concept, it is a cheap commercial vehicle and cheaply maintained, which is the clue to understand its long-term penetration in the Brazilian market.
- 14 The current configuration of the VW modular consortium, for the most recent truck line (Constellation) comprises seven modules, with respective module suppliers: (1) suspension, axles and brakes (Arvin Meritor), (2) chassis assembly (Maxion), (3) wheels and tyres (Recon), (4) body assembly (Delga plus Aethra/Karmann Ghia), (5) engines (Powertrain Inc. – Cummins and MWM joint venture), (6) painting (Carese) and (7) trimming/upholstery (Siemens – VDO).
- 15 For an account of recent developments in technological capabilities accumulation in Brazilian auto-parts suppliers, see Quintão (2008).
- 16 For further discussion of such classification, see Consoni (2004) and Consoni and Quadros (2006).
- 17 For Birkinshaw (1996), world product mandate grants the subsidiary global responsibility for a single product line, including development, manufacturing and marketing that extend the national market.