October, 2007

Global Technology:
Product Development in Brazilian Car Industry

by
Giovanni Balcet (University of Turin, Italy) *
and Flávia Consoni (University of São Paulo, Brazil) *

1. Introduction and summary

The first part of the paper reviews relevant theories on the globalization of innovation processes, knowledge transfer and the international location of research and development (R&D) activities by multinational corporations (MNCs). Multinational innovative and knowledge management (KM) strategies are likely to reflect the inter-action of industry-specific technological characteristics, firm-specific advantages and strategies, and context-specific factors, where agglomeration effects and technological clusters generate locational advantages.

Two different types of strategies and innovative activities of multinational affiliates are identified in the literature.

a. Adaptive knowledge-exploiting activities, pulled by demand, and mainly oriented to adapt products or processes to the specific features of local markets and regulations. Knowledge accumulation is contextual to local production, and it is expected to be incremental.

b. Asset-seeking and knowledge-seeking activities, integrated within international research networks, in order to develop distinctive knowledge assets and technological capabilities. Asset-seeking activities imply a multiplicity of locations of innovation centres within the MNC.

In this paper, this analytical framework is applied to the case of the automotive industry (Section 4), and in particular to the case of foreign affiliates of carmakers in Brazil, a large automotive market, where engineering activities and the accumulation of knowledge in product development have been growing significantly in the last decade (Section 5). Product development and engineering activities are described within the context of the evolving automotive market and production, public policies and multinational strategies.

The methodology of this paper is based on in-depth interviews made in 2005 and 2006 to the four “first wave” affiliates of vehicle assemblers in Brazil (GM, Ford, VW and Fiat). Product and process managers and directors have been interviewed, focussing on local product development and technological activities.

* E-mail: giovanni.balcet@unito.it
* E-mail: flavia.consoni@gmail.com

The authors warmly thank Ruy de Quadros Carvalho of Campinas University (Unicamp) for discussion, empirical data and stimulating ideas; interviewed managers and engineers from General Motors do Brasil, Volkswagen do Brasil, Fiasa-Fiat and Ford do Brasil, for sharing their time and experience; Andrea Goldstein of the OECD Development Centre and Andrea Stocchetti of the University of Venice for useful comments; Silvia Bruschieri for research assistance.

This work sheds light on the limits of the asset-seeking versus adaptive category, as our empirical evidence suggests that the multinational organisation of knowledge transfer is much more complex, and that an evolutionary approach is needed to appreciate the different trajectories of foreign affiliates. Market size and growth rates, history, human resources and technological capabilities, policies and cost advantages are all factors contributing to shape multinational innovation strategies.

2. The international accumulation and transfer of technological knowledge by the multinational corporation: trends and theories

Traditionally, the economic literature on multinational corporations considered the production of new technology and knowledge very concentrated in the multinational headquarters in the home-country, and then diffused internationally via the MNCs. International transfer of technology was at the core of the mechanism described, since the '60s, by the well-known product-life-cycle model (Vernon, 1966). In that model, dynamic inter-relations between innovators and followers explained both the direction and the evolution over time of international trade flows, as well as the crucial decision of innovative exporting firms to become multinational, via foreign direct investment (FDI).

Empirical evidence on trade patterns, FDI and R&D intensity showed a positive correlation in most advanced countries between innovation intensity on the one hand, and export performances and international production on the other hand, but the pace of the product-life-cycle has been shortening over time in the last decades.

In the seminal analysis of Buckley and Casson (1976), communication and transaction costs affect the choice of localising R&D centres. In the first stage of basic research, innovation activities will be decentalised to technological districts, where quality and costs of the human resources are the most attractive. In the intermediate stage of project development, R&D will tend to be centralised in few units worldwide, in order to maximise the economies of scale. The final stage of product development will tend to be located close to production and marketing facilities.

During the '90s, the internationalisation of the production of new technologies within the MNCs, including R&D, projects, process and product innovation, design and patenting, became relevant within OECD-based multinationals, with the exception of Japan. A multiplicity of locations of innovation centres within the MNC resulted from these process. Rival companies tend to cooperate in research, sharing their knowledge in strategic R&D intensive areas, while competing on final markets (Cantwell, 1994).

Foreign ownership affects innovation processes not only because foreign affiliates may be more (or less) innovative than domestic enterprises, but also because of the specific advantages of multinationality (positive effects of operating in various countries), and because MNCs have by definition the advantages of belonging to a group (Ietto-Gillies, 2002).

The pattern of internationalization of R&D by MNCs depends on the interplay between factors of centralisation (economies of scale in R&D; strong technological capabilities in the home country) and factors of international dispersion (centres of excellence abroad; talent pools in

developed as well as in emerging countries) (Sachwald, 2006).

Multinational enterprises search for localised scientific and technological resources, internalising new technologies within their organisations (Narula, 2003; Zanfei, 2000). Technological knowledge and innovative capabilities may in fact be embedded in the firm's organisation, or localised in a given territory (Antonelli, 1995). Agglomeration phenomena and technological clusters generate locational advantages for foreign affiliates (Almeida and Anupama, 2004).

The spread of inter-firm cooperative networks characterises what has been called "alliance capitalism", where oligopolistic competition coexists with inter-firm cooperation (Dunning, 1997). The creation of international inter-firm partnerships, international subcontracting and research-oriented networks, developed since the '80s, have been a consequence of the shortening of the product life cycle and revealed new strategic orientations of MNCs towards technological asset-seeking, while a more interactive relationship and new linkages developed between areas where innovative processes agglomerate, and multinational affiliates (UNCTAD, 2001). Rival companies tend to cooperate in research, sharing their knowledge in strategic R&D intensive areas, while competing on final markets.

Network relations and technological absorption are crucial to the capacity of subsidiaries to transfer knowledge within the multinational group, as they allow the sharing of resources and knowledge. MNCs are characterized by a “double network structure”, internal and external (Castellani and Zanfei, 2006). However, KM is a complex task requiring specific instruments and strategies, especially when knowledge resides in organizational members and in institutional routines and tasks, and when it is tacit and hard to transfer from one part of the organization to another (Nonaka and Takeuchi, 1995).

The degree of autonomy of subsidiary, the amount of intra-group trade and the intensity of knowledge production and absorption are the main factors affecting the intensity and nature of knowledge flows within MNCs (Foss and Pedersen, 2002).

3. Patterns of innovative activities by multinational affiliates.

A variety of patterns are likely to coexist, depending on the specific technological characteristics of industries, as well as on the basic technological infrastructure and economic features of host countries and regions.

A vast amount of literature suggests a basic dichotomy, as it identifies *ex ante* two different types of strategies and innovative behaviours of multinational affiliates. (Le Bas and Sierra, 2002; Balcet and Evangelista, 2005; Sachwald, 2006; Castellani and Zanfei, 2006).

A. Adaptive innovative activities and knowledge-exploiting strategies

In this case, innovative activities abroad are mainly oriented to adapt products or processes to the specific features of local demand, local resources and production conditions, policies and regulations. R&D is contextual to local production, and it is expected to be incremental and limited to the product development, not including general-purpose and basic

research.

The main motivation of MNCs in this case is the access to domestic markets, and the exploitation abroad of innovative advantages, transferred from the home country or from other affiliates of the group. Therefore, this pattern represents a first stage of the internationalisation of innovation processes, consistent with the product-life-cycle theory (Vernon, 1966), and its hypothesis of unidirectional technology transfer.

This pattern corresponds to the creation of local development centres, geographically dispersed to serve the needs of domestic markets (Sachwald, 2006). It has also been defined in terms of “asset-exploiting” or “home-base exploiting” R&D (Dunning and Narula, 1995).

The multinational affiliates following this strategic orientation are characterised by relevant intra-group technology inflows, low export intensity, and few technological linkages and cooperative agreements with domestic companies and research institutions.

B. Knowledge-seeking innovative activities within regional or global strategies

In this second pattern, innovative activities are carried out within international research networks, in order to develop distinctive knowledge assets and technological capabilities. In several high-tech industries, new FDIs have been made aiming at the acquisition of new technologies and the building of networks for international sourcing of scientific and technological resources, and some MNCs have located segments of basic research abroad.

Global or regional research laboratories and development centres are the main instruments to implement this strategy, as part of multinational innovation networks, in which foreign affiliates share knowledge and technology (Sachwald, 2006).

Global research laboratories source technology and monitor scientific developments. The proximity of technological districts, universities and research institution, as well as the availability of high level human resources, strongly support this strategy, implemented through acquisitions of existing R&D units, greenfield R&D investments or technology-oriented joint ventures.

Global development centres, carrying out tests, specific studies, software engineering and design, correspond to the relocation of product and process development activities, lowering their costs and improving the cost-efficiency ratio. They are often located in emerging countries with important human resources and growing technological capabilities, and they are upgrading from subcontracting to more advanced tasks.

Agglomeration phenomena and technological clusters generate locational advantages for these affiliates. Technological linkages and cooperations with domestic companies and research institutions may arise.

When knowledge creation is based on networks and local clusters, a high degree of autonomy of the multinational affiliate may be a condition of success (Foss and Pedersen, 2002).

As a consequence of these "strategic asset-seeking activities" or “home-base augmenting R&D units” (Dunning and Narula, 1995), multinational affiliates will be able to export technologies, patents and new components and products, in particular within their group.

4. Globalization of the Product Development Process in the Automotive Industry: Evolving Patterns

In this Section, we shall apply this basic dichotomy to the case of the automotive industry in general. Four case studies of multinational carmakers in Brazil will be presented in Section 5.

If we look to the automotive industry, the R&D activities manly consist in product development (PD), process innovation related to machinery, automation and organizational change, and design. Basic research represents a limited amount of total R&D spending (Chanaron, 1998).

The internationalisation of these activities can be interpreted as a significant qualitative indicator of the internationalisation pattern in general of a given carmaker or component supplier (Pries, Schweer, 2004). Different steps of the complex PD process, from concept creation to prototypes and testing, may be geographically distributed over plants and research units in different countries and areas.

Applying the general dichotomy, discussed in section 3, to the specific case of the automotive sector is a very stimulating exercise, as it sheds light on the limits of the asset seeking versus adaptive category.

Empirical studies suggest that an evolution from pattern A to pattern B can be observed. Technological competencies in a first stage are created or acquired from local clusters by a multinational affiliate to cope with local adaptation needs; but in a second stage they grow, and foreign affiliates are able to transfer technologies towards the multinational network (Balcet, Enrietti, 2002). In some cases, the foreign affiliate can accumulate specific knowledge and capabilities (Birkinshaw 1996), receiving specific R&D missions within the multinational group. Therefore, a dynamic approach is needed in order to analyse empirical evidence.

Therefore, we can make the hypothesis of the following sequence:

Adaptive Incremental Innovation → Learning Process → Accumulation of Technological Knowledge and Engineering Competencies → Building of Areas of Excellence → Transfer of Knowledge and Technology within the Multinational Group

Technological infrastructure, innovation policies, human capital and education systems deeply affect the attractiveness of the host country and therefore the interest of MNCs for knowledge seeking strategies.

Moreover, power relations matter, as they may affect the international location of PD processes. A strong competition may arise among affiliates and plants within the same multinational group over the locational choice of new innovation and PD projects, and for the distribution of resources, competencies and functions (Pries and Schweer, 2004).

Also inter-cultural relationships may affect the success of multinational technological projects, as it is well illustrated by the story of the integration of Skoda within the VW group, giving rise to a sort of “hybrid corporate culture” (Jung et al., 2004). Temporary transfer of engineers and technologists among different units of the multinational group, as well as the creation of international teams, are viewed by concerrned managers as crucial instruments to transfer non codified knowledge (Foss and Pedersen, 2002).

In some cases, PD processes have been internationalised for niche models, such as the New Beetle, produced in Mexico by VW, and Mercedes-Benz M Class, produced in the US by DaimlerChrysler (Pries and Schweer, 2004).

Generalising from Consoni and Quadros (2006), we can identify five main steps of technological and engineering competencies developed by foreign affiliates of automotive multinationals in emerging countries (see table 1).

Table 1. Levels of technological capabilities and innovation by automotive multinational affiliates in emerging countries

a. Nationalisation of components: increase of local content
b. Adaptation of models from foreign platforms to domestic market features and regulations, through incremental innovation and re-styling
c. Partial derivative projects from global platforms for regional markets
d. Complete derivative projects from global platforms for regional or global markets
e. New platforms and vehicle architecture, worldwide product mandate

Source: Adapted from Consoni and Quadros (2006)

The issue may be raised on the relation between this articulated taxonomy and the traditional adaptive versus asset-seeking dichotomy. The levels (a) and (b) correspond to different degrees of typically adaptive strategies, including re-engineering of foreign platforms. Levels (c), (d) and (e) imply the presence of asset-seeking motivations by multinational affiliates. However, table 1 suggests continuity between different levels, consistent with an evolutive approach, instead of a sharp opposition of main strategic goals, as suggested by the simple dichotomic scheme.

This approach seems to be especially appropriate for the case of automotive industry in emerging countries, where the most part of the firms are affiliates of MNCs companies, the need for adaptation to market specificities is crucial, and the transition between different levels of technological activities is a common feature.

We shall now move to discuss the case of carmakers in Brazil.

5. Product Development in Brazilian Automotive Industry: Adaptation, Areas of Excellence, Linkages

From a historic perspective, protectionism and import-substitution policies had a major role in the early growth of the Brazilian car industry, till the 1980s. Four multinational car assemblers (Ford, General Motors, Volkswagen and Fiat) operated at that time in the country within multi-domestic market-oriented strategies. They represent the first wave, i.e. the first movers to this promising market.

In the early 1990s, a policy change towards trade liberalisation was announced, followed soon by the regional integration initiative of Mercosul, consolidated in 1994 by the Ouro Preto agreement.

The first policy change increased domestic competition and imports of vehicles, while Mercosul created the conditions for an upgrading of multinational strategies, from multi-domestic to regional configurations, through the productive specialisation of affiliates located in Brazil and in Argentina (Lung, 2006). The outcome was a complex division of labour intra-multinational groups, based on the specialisation of Brazilian affiliates in high volume models and some components, and the localisation in Argentina of lower-volume models and other components (Laplane and Sarti, 2004).

In the 1990s, Brazil moved from highly protectionist policies to a regime of managed trade within a regional integration process. The automotive industry was strictly regulated by negotiated rules, including local content requirements and trade balance requirements.

As a consequence, investments by car assemblers in Brazil rose from US$ 5.4 billions during the 1980s to US$ 16.6 billions in the 1990s (Anfavea 2006). The largest share of such investment was made by car assemblers already located in Brazil, either to modernise local assembly units, to upgrade product portfolios, which were obsolete compared to international standards, or to build greenfield assembly units. New entrants, i.e. the second wave carmakers, accounted for the other share of investment. Toyota, Honda, Renault, PSA Peugeot-Citroën, VW Audi and Daimler Benz opened new car plants between 1997 and 2002 (table 2). After the 1990's, all the Brazilian automotive affiliates became increasingly integrated within multinational networks, either on a regional or on a global scale.

Table 2. Car makers in Brazil: localization

FIRST WAVE (BEFORE 1997)	
Ford	SP* (São Bernardo Campo, São Paulo and Taubaté)
General Motors	SP (São Caetano Sul and São José dos Campos)
Volkswagen	SP (São Bernardo Campo and Taubaté)
Fiat	MG* (Betim)
SECOND WAVE (AFTER 1997)	
Honda	SP (Sumaré)
Toyota	SP (Indaiatuba)
Peugeot/Citröen	RJ* (Porto Real)
Mercedes-Benz	MG (Juiz de Fora)
Volkswagen/ Audi	PR* (São José dos Pinhais)
Renault	PR (São José dos Pinhais)
General Motors	RS* (Gravataí)
Ford	BA* (Camaçari)

Source: Adapted from Consoni (2004)

* SP (São Paulo); MG (Minas Gerais); RJ (Rio de Janeiro); PR (Paraná) RS (Rio Grande do Sul); BA (Bahia)

5.1. Evolving Product Development Strategies

Innovation activities, local engineering and PD processes have been developed mainly by the four carmakers of the first wave, while newcomers tend to centralise R&D and innovation activities in their respective home

countries. However, divergent trajectories can be observed during the 1990s (Quadros and Queiroz, 2001).

• GM and Fiat engaged strongly in developing regional derivatives from global platforms. It was the case of GM's Corsa (pickup, wagon and sedan versions) and Astra Sedan, followed by the Blue Macaw project (Consoni, 2004), while Fiat developed a specific platform for emerging markets, within a strategy of "focused globalization" (Balcet and Enrietti, 2002). Both carmakers defined a regional mission for their Brazilian technology and engineering centres.

• Ford and VW both moved to a centralisation of PD and innovative activities after the experience of their joint venture Autolatina, created in 1987, ended in 1994. This strategic choice implied a reduction of technological activities of both car makers in Brazil.

The case of Ford is very illustrative. Ford's "2000 Program" included the goal of the rationalisation and centralisation of R&D activities worldwide. As a consequence, during the late 1990's Ford completely abandoned its local PD strategy in Brazil and dismantled its product engineering area. This radical change implied that all vehicles Ford launched in Brazil needed to be adapted in the US or Europe. However, this proved to be an expensive and inefficient strategy, and Ford faced serious problems when developing Brazilian derivatives within the Amazon Project, the first to be launched in the new "industrial condominium" in Bahia State. The original plan of Ford was to centralise the whole vehicle project in Ford England Technology Centre, including the design of derivatives for emerging markets. Brazilian engineers were expected to participate marginally, providing inputs related to market requirements. The Amazon Project led to the transfer of responsibility for the Brazilian derivatives to Ford US, which sub-contracted most of the job to engineering services suppliers. The overall result was a major delay in the Brazilian launching of the new vehicles and the consequent (and further) reduction of the market share of Ford in Brazil.

Soon it became clear that the differences between emerging market and Europe were so great that they could not be dealt within a centalised project. Recognising that the absence of local support to PD was behind Ford's continuous losses, Ford reconstructed its Brazilian engineering capabilities, and hired product engineers again. However, the localisation of the PD department in a greenfield area such as Bahia State involved problems of recruitment of engineers and qualified technicians; most of them had to move from other Ford units located in São Paulo State.

In the same period, also VW decided to centralise the R&D and PD strategy, reducing engineering activities in Brazil, in line with the choice to adopt a unique product strategy, based on global platforms worldwide. According to this strategy, all vehicles launched in Brazil should be derived from a global project, with limited adaptation, in order to match the most critical local technical requirements.

In the early 2000s, however, also VW significantly re-decentralised PD and engineering to Brazilian technology units, through relevant new investment in São Paulo and Paraná States.

The strategic change of Ford and VW had the same motivation: the poor results of the centralised option showed that a large and growing emerging market, like Brazil, could not be served by a leading carmaker without a sufficient technological and engineering capability located in the host country.

These cases of evolution to centralisation, followed by a new re-decentralisation option, also provide interesting evidence on a trial-and-error approach.

Second wave carmakers are still at an earlier stage in mid-2000s. All of them have launched in the Brazilian market products designed for mature markets, whose re-engineering (adaptation to local technical and taste conditions) has been mainly carried out in Europe, US or Japan. As a consequence, they tend to centralise the production of new technology in their home countries, or in regional headquarters abroad, with poor local engineering. In our view, the main reason (although not the unique) behind the centralisation of PD is the low scale of newcomer operations.

More recently, however, some second wave car assembles have reinforced the local engineering teams, integrating them with R&D centres abroad: the case of Renault being the most illustrative one.

In the early XXI century, a new dichotomy emerges between two groups of first wave carmakers:

- GM and VW represent the most advanced stage of PD process in Brazil, including complete derivative projects (Meriva and Fox respectively) for the European market, corresponding to the stage (d) in table 1;
- Ford and Fiat show a more limited experience and represent a less developed stage of domestic engineering, corresponding to stage (c) in table 1.

A synthetic overview of the main characteristics of product development processes carried on in Brazil by the four first wave carmakers in 2005 is provided by table 3. It is based on interviews to top managers of Brazilian automotive affiliates, responsible for PD, process engineering and strategic planning.

All the first wave carmakers went through the first two steps of table 1, increasing local content, through vertical integration or increased purchase from local suppliers, and adapting models to domestic market. This process of “tropicalization” was considered essential to meet local specificities, such as bad road and vehicle use conditions, climate and fuel differences, domestic regulations, lower consumer income and peculiar consumer tastes.

5.2. Areas of Excellence

Analysing the experience of the four main carmakers, four areas of specialization and excellence may be pointed out.

- Small engines, up to 1000 cc. Due to the dominant share of subcompact cars in the domestic market, the Brazilian car makers developed their competences in the design of small and efficient engines, with greater power than the previous generation. This segment has been stimulated by the policy of “carro popular” (popular car, defined as a low price and low powered car), through tax incentives.

- Flexible engines and related powertrain. Stimulated by Brazilian energy policies of diversification implemented since the 1970s,

Brazilian subsidiaries of assemblers and suppliers[1] have co-designed the so-called "flexfuel" system, which can use both traditional gasoline and alcohol (cane-based ethanol), or a proportion of both. Flexfuel engines, introduced in 2003, rapidly became the domestic standard. Consequently, the share of flexfuel vehicles reached 80% of the Brazilian market in 2006. The forecast is that in the future Brazilian carmakers will no more produce traditional gasoline cars.

- Local materials, less expensive or more adequate to local needs, tastes, income and fuels. It is the case of plastics, alloys, and powertrain components adapted to the use of ethanol. Assemblers' materials labs are mostly oriented to make research on the resistance to oxidation and corrosion, as the Brazilian fuel, with alcohol in its composition, is much more corrosive than gasoline. The materials labs also support R&D on materials replacement and solutions aimed at reducing the cost of entry level vehicles.

- Suspensions. More robust suspension modules, adapted to rough road conditions and local ways to use vehicles, have been developed. Some suppliers have global technological competencies in this area.

It is worth noting that specific features of Brazilian market, production conditions, regulations and policies shape all these areas. This strongly confirms, in this specific case, the relevance of the sequence underlined in Section 4:

Adaptive Innovation → Learning Process → Accumulation of Technological Competencies → Areas of Excellence → Export of Technology within the Multinational Group.

The most advanced achievements of Brazilian affiliates in PD processes are represented, in the early 2000s, by two niche models, derived from global platforms: Meriva for GM do Brasil (GMB) and Fox for VW do Brasil. They both represent examples of case (d) in Table 1, i.e. complete derivative projects from global platforms, developed and coordinated by Brazilian engineering teams. However, the performances of the two models were different. Meriva project was launched at first in Brazil in 2002 for the domestic market, and later for the European market. The vehicle, assembled in Brazil by GMB, and in Germany by Opel, has been a success on the European market. Fox was developed by VW do Brasil, and it is exported to Europe since 2005, but in 2006 the company announced the progressive reduction of this export flow, due to the appreciation of the Brazilian currency, and to poor performance on this model in Europe.

Interviewed managers pointed out that Brazilians engineers, generally less specialised, are more oriented to cost saving, with respect to European or American engineers, usually oriented to the best technological solution. From that point of view, it is interesting to note that, even if the VW group is considered a quite centralized multinational, a direct cooperation has been

[1] The Brazilian units of the multinational componenet suppliers Bosch, Delphi and Magneti Marelli worked with the carmakers in the local development of the flexfuel systems.

reported to exist between engineers from Skoda and from VW do Brasil: it is based on a common cost-saving approach, in order to design cheaper technological solutions.

Since January, 2005, GMB, that was already responsible for a vast region named LAAM (including Latin America, Middle East and Africa), became one of the five Global Engineering Centres of GM worldwide. From GMB point of view, this confirms its path to global integration and implies the need to increase the number of technical professionals[2].

If we refer to Table 1, the only technological level not yet existing in Brazil is a completely new platform, according to Consoni (2004) analysis. In the mid-2000s, however, this situation is evolving, due to the growth of PD capabilities of Brazilian affiliates and the progressive insertion of some of them in the global innovation networks of their multinational groups.

5.3. Linkages and mechanisms of intra-group knowledge flows

Multinationals combine internal networks of affiliates with external networks of linkages and collaborations, in order to integrate different economic and technological contexts (Castellani and Zanfei, 2006). In relation to the Brazilian automotive industry, we can identify two main ways of acquisition and diffusion of knowledge in and between foreign affiliates:

- technology-oriented agreements and cooperation linkages with both public research institutions (i.e. universities and technological centres) and market actors (i.e. suppliers of components or engineering and service companies)
- interaction and cooperation within the same multinational group.

Cooperative relations within the host country, including technological outsourcing, are crucial in order to qualify knowledge-seeking strategies, as defined in Section 3, and characterise the levels (c), (d) and (e) of table 1. In fact, multinational affiliates following asset-seeking and knowledge-seeking strategies within regional or global networks are keen to exploit domestic technological capabilities and human resources, *inter alia* through cooperative agreements (Balcet and Evangelista, 2005).

Table 3 provides evidence, based on direct interviews, on the most relevant linkages developed by the four first wave carmakers.

A tendency exists to the concentration of research (the “R” of the R&D) in the headquarters and major international R&D centres, while the “D” activities, especially product development, tend to be located in Brazil, although the levels of knowledge complexity vary among the car makers.

In relation to cooperative behaviour between automotive industry and Brazilian research institutions, a recent study showed a change towards technological outsourcing and cooperative research (Quadros et al, 2005 and 2006). This investigation pointed out that the frequency of contacts and contracts between foreign firms (suppliers and assemblers) and Brazilian research institutions is much larger than usually acknowledged. There is some concentration of such contracts in the fields of Powertrains, Fuels, Materials and Manufacturing technologies, that are the most demanded technologies in the country (Quadros *et al*, 2006). However, it is interesting to notice that the frequency of service contracts is much higher than that of

[2] In 2004, GMB increased the number of engineers in the Product Engineering Department from 500 to 660. In 2007, the number of professionals in this same Department was around 1600, including 1100 engineers.

research contracts. Services, in this case, are generally related to what could be called engineering with science fundamentals, rather than short term, testing-like services. In most contracts, the Brazilian universities and research centres supplied solutions to the local engineering teams of foreign affiliates.

This evidence could show a new move towards asset-seeking strategies by automotive multinationals in the country. This could represent a major strategic change with respect to the up-to-now dominant adaptive strategies.

Another importante case of cooperative linkages concerns engineering and service companies. Although this practice has been frequent for all assemblers we have interviewed, the case of Ford do Brasil is worth to mention. Ford considered that the practice of sub-contracting engineering services during the development of the Amazon Project worked very well. Consequently, in 2006 around 50% of the PD staff of Ford do Brasil were employees of external agencies, i.e. engineering service companies. Ford and outsourced engineers work together, doing the same task and sharing the same responsibilities about the PD activities.

The second way of knowledge diffusion is the interaction with other affiliates within the same multinational group. Video conference and other types of information and communication technologies (ICT) and equipments were used, in addition to face-to-face meetings, to promote the diffusion and sharing of the knowledge among two or more units world-wide. Moreover, we can mention at least two practices that have been implemented by interviewed subsidiaries. The first one is the adoption of concurrent engineering concepts and techniques. They have increased the integration among subsidiaries in different countries and made possible greater synergy between technical teams. Such integration allowed the Brazilian subsidiaries to be in close contact with headquarter or central laboratories, acquiring their best technical practices. This interaction contributed to the improvement of technological competencies of Brazilian subsidiaries.

Another important instrument to promote intra-group integration, to transfer knowledge, especially non codified, and to stimulate the cooperation among multinational units, was the temporary transfer of engineers and technologists, i.e. the exchange of staff, as well as the creation of international teams. Affiliates in Brazil received for long periods many foreign residents, and many Brazilian engineers spent periods of time abroad in training, working in headquarters or foreign affiliates. The number and qualification of residents varied according to the specific project. Such practice has been an important learning mechanism and contributed to both the strengthening of existent capabilities and the creation of new PD capabilities. Moreover, the exchanging residents facilitated efficient communication and knowledge transfer among units.

The experience of the Meriva Project, developed in co-operation between GM Brasil and Opel, was very illustrative to this respect, as pointed out by Consoni (2004) and Consoni and Quadros (2006). Although GMB was technically responsible for the program, there was a strong partnership between the Brazilian and the German teams during every phase of the project, including the exchange of residents. The purpose was not only to supervise the activities, but also to exchange experiences and knowledge regarding vehicle requirements for both European and South American markets, which are different in aspects such as emission, noise, safety and

recycling standards. Residents in Germany and in Brazil, most of them engineers, followed the activities and strengthened the contacts between the two units.

Table 3. Product Development in Brazilian Automotive Affiliates (2005 and 2006)

	GENERAL MOTORS DO BRASIL	WOLKSWAGEN DO BRASIL	FIASA - FIAT	FORD DO BRASIL
HUMAN RESOURCES	1.030 employees in PD unit (660 engineers) Share of PD Employees on total employees: 4.8 %	1.110 employees in PD unit (660 engineers) Share of PD Employees on total employees: 4.9 %	490 employees in PD unit (252 engineers) Share of PD Employees on total employees: 2.9 %	1080 employees in PD unit * (650 engineers) Share of PD Employees on total employees: 6.5 % *
LOCALIZATION	São Caetano do Sul and Indaiatuba/ Proving ground (São Paulo)	São Bernardo do Campo (São Paulo)	Belo Horizonte (Minas Gerais)	Camaçari (Bahia); Tatuí/ Proving ground (São Paulo)
TECHNOLOGICAL INFRASTRUCTURE	PD Centre Styling and Design Centre Prototypes Centre Materials Laboratory Virtual Proving Ground Physical Proving Ground and laboratories for structural analysis, security, NVH (Noise, Vibration, and Harshness) and crash tests.	PD Centre Styling and Design Centre Prototypes Centre Materials Laboratory Security and Crash Test Centre Small proving ground	PD Centre Styling and Design Centre, connected with Fiat Auto in Turin Prototype Centre Noise and vibration testing facility Virtual simulation of road condition, tests of materials and components	PD Centre Styling Centre Prototypes Centre Virtual simulation Proving Ground, laboratories of emission, NVH (Noise, Vibration, and Harshness), Vehicle Dynamics, crash test

* including 497 external agency employees

* including 497 external agency employees

CAPABILITIES AND STRATEGIES	One of the five Global Engineering Centres Responsibility for the PD for the LAAM region (Latin America, Africa and Middle East) Close contact and interaction with all the other four Global Engineering Centres (GM USA, GM Europe Opel; GM South Korea Daewoo, GM Australia) Complete and partial derivatives from foreign platforms Tropicalisation of the models for the regional market Inter-action with Opel Engineering Centre in Germany Re-styling Prototypes Homologation.	Product Development for emerging markets Complete and partial derivatives from foreign platforms Tropicalisation of the models for the regional market Re-styling Prototypes Homologation Inter-action with VW Technological Centre in Germany and with Skoda in the Czech Republic	Tropicalisation of the models for the local market Re-styling (Palio) and derivative models (Novo Palio, 2003) Involvement in the strategy of focused globalisation of Fiat Auto (project 178: since 1994) Transfer of the Palio/Siena platform, for incremental product innovation and re-styling Wind tunnel and proving ground lacking (till 2005, GMB facilities used, within Fiat-GM alliance) Homologation Focus on emerging countries No product development for European markets	Tropicalisation of the models for the local market Re-styling PD for emerging markets, supported by headquarters and by external engineering companies Derivative models within Amazon project since 2002 (Novo Fiesta, Fiesta Sedan, EcoSport) for regional markets Homologation
AREAS OF EXCELLENCE	Global responsibility for suspensions and flexible engines Focus on low-cost solutions (e.g., electrical systems) SUV (sport utility vehicle)	Development of flexible and small engines Suspensions	Development of flexible engines. Suspensions	Development of flexible and small engines. Bakes and transmissions Process Development
TECHNOLOGICAL CO-OPERATION	With suppliers With Engineering Universities of UFSCar; USP São Paulo, Unicamp and Instituto Mauá de Tecnologia	With suppliers Research contracts with UFSCar (e.g., injection) Contracts with European and US engineering companies Joint-ventures with engineering start-ups in Brazil	With suppliers Joint research group with CNPQ (National Council for Scientific and Technological Development) With the Federal University of Minas Gerais With the PUC of Minas Gerais With the University of Brasilia	With Suppliers Contracts with engineering companies. Educational and recruiting projects with Brazilian universities, but no research cooperation

Source: Consoni (2004) and our interviews to corporate managers (2005 and 2006)

6. Concluding remarks

Emerging countries are a very interesting field of experimentation of new trends to internationalisation of knowledge and of technological and organisational innovation. Among them, Brazil represents one of the major cases of interest, because of the size of its market, its development policies and its qualified human resources.

Empirical evidence on this country suggests that the multinational organisation of PD processes is much more complex, both from the technological and from the organizational point of view, than it could be expected from a simple dichotomic approach, opposing adaptive strategies to asset-seeking strategies. In real world, not only are typologies and strategies much more articulated, but also they evolve constantly.

We can summarise the following results from this case study.

- Technological R&D activities have been till now limited in the Brazilian automotive affiliates, and the largest part of new technological knowledge was transferred from R&D units located abroad. This emphasizes the importance of the mechanisms of knowledge diffusion within the multinational group.

However, relevant and innovative solutions to the problems posed by the development and adaptation of vehicles and related new knowledge have been developed internally by the product and process engineering areas of the Brazilian subsidiaries.

- Local market size and growth rates strongly affect PD and engineering activities, as a major driver for adaptive innovation and the related accumulation of competencies, that in a second stage can give rise to areas of specialisation and excellence. Four main technological areas of specialization have been identified by our fieldwork. Demand-pull dynamics and “à la Linder’’ effects are crucial mechanisms for innovation generation and knowledge diffusion and absorption. The cases of Ford and VW in Brazil and their strategic changes, after the poor performances generated by a centralisation strategy, illustrate this point.

- History matters, as cumulative effects and incremental processes are crucial in knowledge creation and diffusion. Path-dependency can be observed. An evolutionary approach is needed in order to appreciate the different trajectories of foreign affiliates from adaptive activities to the accumulation of knowledge, the creation of specific competencies and the search for local technological resources. This sequence can be observed in the case of first comer carmakers in Brazil. However, an heterogeneity of technological trajectories of carmakers in the same country may therefore be observed, within the first wave multinationals, according to different corporate approach to global technology and engineering.

- Human resources, education policies and technological infrastructure and capabilities are main attracting factors vis-à-vis innovation-oriented multinationals, and deeply influence the effectiveness of knowledge transfers. They should be appreciated jointly with cost advantages and the cost-efficiency ratio. These

factors together explain the creation and the enlargement of specialised PD centres in emerging countries like Brazil.

• Policies matter, in order to shape the domestic market and to develop domestic capabilities and resources. Not only industrial policies, regulations, technical standards and energy policies, but also trade and regional integration policies and local content requirements shaped the demand of cars and deeply influenced its supply: the most known examples in Brazil being those of “popular car” policy and the energy diversification policy.

An interesting field for further research is represented by the way organizational models and power relations internal to multinational groups affect locational choices of new technological project, and their subsequent implementation.
Another open and crucial issue concerns the involvement of the system of local suppliers, both national and multinational, in PD and innovation processes.

References

- P. Almeida and A. Phene, Subsidiaries and Knowledge Creation: the Influence of the MNC and Host Country on Innovation, *“Strategic management Journal”*, 25, 2004.
- Anfavea, Brazilian Automotive Industry Yearbook. Anfavea, São Paulo, 2006.
- C. Antonelli, *The Economics of Localised Technological Change and Industrial Dynamics*, Kluwer, Boston, 1995.
- C.Antonelli and M. Calderini, The Governance of Knowledge Compositeness and Technological Performance: The Case of Automotive Industry in Europe, Eurodite Working Paper, 2006.
- G. Balcet and A. Enrietti, The Impact of Focused Globalisation in the Italian Automotive Industry, “*Journal of Interdisciplinary Economics*”, vol. 13, n. 1 – 3, 2002.
- G. Balcet and R. Evangelista Global Technology: Innovation Strategies of Foreign Affiliates in Italy, “*Transnational Corporations*”, vol.14, n. 2, August 2005
- J. Birkinshaw, How multinational subsidiary mandates are gained and lost. *Journal of International Business Studies*, vol.27, n.3, 1996.
- P.J. Buckley and M. Casson, *The Future of the Multinational Enterprise*, MacMillan, London, 1976.
- J. Cantwell, *Transnational Corporations and Innovatory Activities*, Routledge, London, 1994.
- D. Castellani and A. Zanfei, Multinational Firms, Innovation and Productivity, Edward Elgar, Cheltenham, 2006.
- J.J. Chanaron, Automobiles: a Static Technology, a 'Wait-and-see' Industry? “*Technology Management”*, vol.16, n. 7, 1998.

- F. Consoni, Da tropicalização ao projeto de veículos: um estudo das competências em desenvolvimento de produtos nas montadoras de automóveis no Brasil, PhD Thesis, University of Campinas, 2004.
- F. Consoni and R. Quadros, From Adaptation to Complete Vehicle Design, A Case Study of product development Capabilities in a Car maker in Brazil, "*International Journal of Technological Management*", vol. 36, n. 1-2-3, 2006
- I. Costa and S. Queiroz, Foreign Direct Investment and Technological Capabilities in Brazilian Industry, "*Research Policy*", 31, 2002
- J. Dunning, Multinational Enterprises and Globalization of Innovatory Capacity, "*Research Policy"*, 23, 1994.
- J. Dunning, Alliance *Capitalism and Global Business*, Routledge, London, 1997.
- J. Dunning, R. Narula, The R&D Activities of Foreign Firms in the United states, "*International Studies of Management & Organization*", vol 25, 1995.
- N.J. Foss and T. Pedersen, Transferring Knowledge in MNCs: the Role of Sources of Subsidiary Knowledge and Organizational Context, *"Journal of International Management"*, 8, 2002.
- G. Ietto-Gillies, *Transnational Corporations. Fragmentation amidst Integration*, Routledge, London, 2002.
- A. Jung et al., Culture Matters. The Success Story of the Volkswagen – Skoda Venture, in : M. Faust, U. Voskamp, V. Wittke (editors), European Industrial Restructuring in a Global Economy: Fragmentation and Relocation of Value Chain, SOFI, Gottingen, 2004
- M. Laplane and F. Sarti, Mercosur: Interaction Between Sustainability of the Regional Automobile Industry, in J. Carrillo, Y. Lung, R.van Tulder (Editors), Cars, Carriers of Regionalism?, Palgrave/GERPISA, 2004
- C. Le Bas and C. Sierra, Location Versus Country Advantages, *"Research Policy*", vol. 31, 2002.
- Y. Lung, le Mercosur dans les trajectoires d'internationalisation des firmes automobiles, *Cahier du GRES 2006-03*, Bordeaux, 2006
- R. Narula, *Technology and Globalisation*, Polity Press, 2003.
- R. Narula and A. Zanfei, Globalization of Innovation: the Role of Multinational Enterprises, in J. Fagerberg, D. Mowery and R. Nelson (editors), The Oxford Handbook of Innovation, Oxford University Press, Oxford, 2005.
- I. Nonaka and H. Takeuchi. *The Knowledge-Creating Company.* New York : Oxford University Press, 1995.
- L. Pries, O. Schweer, The Product Development Process as a Measuring Tool for Company Internationalisation? The Case Studies of DaimlerChrysler and Volkswagen, "*Journal of Automotive Technology and Management*", 1, 2004.
- R. Quadros and S. Queiroz, The Implication of Globalisation for Distribution of Design Competencies in the Auto Industry in Mercosur, *Actes du GERPISA*, 32, 2001.
- R. Quadros, F. Consoni and R. Quintão, Cooperative Research Between Firms and Research Institutions: a New Look into R&D in the Brazilian Automotive Industry, GERPISA International Conference, Paris, June 2005.

- R. Quadros, F. Consoni, G. Vieira and R. Quintão, Mapping out Technological Capabilities in Research Institutions as Tool for Prospecting R&D Outsourcing Opportunities: a methodology developed for the R&D centre of a major car assembler. XXIV Simpósio de Gestão da Inovação Tecnológica, Gramado/RS, October 2006.
- F. Sachwald, Location Choices Within Global Innovation Networks: the Case of Europe, *Journal of Technology Transfer*, September 2006
- UNCTAD, World Investment Report 2001. Promoting Linkages, UNCTAD, Geneva, 2001
- UNCTAD, World Investment Report 2005. Transnational Corporations and the Internationaization of R&D, UNCTAD, Geneva, 2005
- R. Vernon, International Investment and International Trade in Product Cycle, "*Quarterly Journal of Economics*",1966
- A. Zanfei, Transnational Firms and the Changing Organization of Innovative Activities, "*Cambridge Journal of Economics",* 24, 2000