R&D outsourcing to research institutions: a new look into R&D in the Brazilian automobile industry[1]

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1. Introduction

Vehicle assemblers and suppliers have been stepping up R&D activities in Brazil (Quadros and Queiroz, 2001; Consoni and Quadros, 2003; Carneiro-Dias et al., 2003; Consoni and Quadros 2005). This is part of the process of internationalization of manufacturing and design activities in the automobile industry. This process has substantially increased the integration of firms located in Brazil into the global production network and helped substantial growth in Brazilian exports of parts and vehicles. However, the literature shows that R&D mandates of Brazilian subsidiaries of multinational assemblers and auto-part producers have been concentrated on product development and adaptation rather than applied research. The situation in the remaining, large Brazilian suppliers is not different. Research on new automotive technologies in the country is marginal and local development activities draw on either technological innovations developed in central labs (in the case of MNCs) or on licensed technologies.

The aim of this paper is to explore recent changes in the nature of R&D in the Brazilian automotive industry, focusing the issue of whether and how research on automotive technologies has been relying on outsourcing and cooperative research between firms and research institutions (RI: universities and public labs). Research outsourcing and research partnership with RI is growing as a strategic option for corporations to reduce R&D costs and fertilize research programs (UNCTAD, 2002). In the case of developing countries, sourcing RI knowledge is even more important, given the lack of resources of all kinds for research within firms. In Brazil, it must be added that most government policies and programmes for promoting and funding private R&D, including the recently approved Innovation Law, encourage, if not require firms' partnership with RI.

The paper[2] is in part based on an on-going research project commissioned by Renault to Unicamp; the objective of the project is mapping research competencies in Brazilian RI. We draw on data on cooperative research and outsourcing between RI's research groups and corporations from all industrial sectors, in the field of materials technologies[3].Data refer to 37

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[2] This is the project "Capabilities and opportunities involving technologies applicable to the automotive sector – mapping out of the Brazilian research institutions", which is commissioned by the Renault to GEMPI (Research Group on Firms and Innovation) at DPCT/Unicamp.
[3] This includes a vast range of technological areas, such as composites, polymers, metal alloys, ceramics, vitreous materials, biomaterials and so on. Other technological fields are the subject of the project current and future research.

research groups in Brazilian universities and research labs, most of them working on frontier technological issues in disciplines such as Chemistry, Physics, and Materials, Chemical, Mechanical and Metallurgical Engineering[4].

The paper will emphasize three main findings. First, the study reveals that the outsourcing of R&D and technological services by Brazilian assemblers and suppliers to RI is larger than usually acknowleged and has been growing. It is less known due to the fact that it rarely draws on government funding. Second, R&D outsourcing concentrates in some particular fields – composites and polymers, metal alloys, biomaterials – in which there are considerable research competencies in Brazil. Third, in spite of recent growth, cooperative research with automotive firms is considerably fragile in terms of continuity and depth. These findings lead to the policy implications of the paper. There is ground for substantially increased research cooperation between firms and RI in the Brazilian automobile industry; there is a critical mass of firms, which are interested and mature for such cooperation, whereas Brazilian RI have accumulated significant knowledge and research experience in the relevant technologies. Yet, the policy framework is not adequate: while the priorities in S&T policy does not include in practice transport technology, vehicle suppliers and assemblers are focusing more on economic and market rather than technology issues.

The paper is organized in seven sections, including this introduction. Section 2 is based on previous reseearch and presents an analytical picture of the evolution of R&D in the Brazilian auto industry, showing that internationalization of R&D by global assemblers ands suppliers has helped the internalization of product development capabilities in local subsidiaries and their suppliers.Yet, such global corporations keep technological research centralized in their major R&D labs in Europe and the US. The following section (3) introduces an empirical framework for the discussion of the interaction between firms and RI in Brazil, comparing the automobile industry with other industrial sectors. While cooperative research with RI is rare in the Brazilian auto industry, the situation is opposite as regards R&D outsourcing: Brazilian suppliers and assemblers are among the leaders in terms of volume of R&D outsourcing. However, the aggregate data on which such conclusions are based do not reveal the types of links and the content of such outsourcing. Here, the Renault-Unicamp project and database comes in to bring new data on this subject. Thus, section 4 is dedicated to explaining the methodologies adopetd in such project, which provided the data explored in the following sections. It is worth reminding the reader that so far we have been able to explore only the area of materials technologies. The complete picture, involving other technological areas, is expected to be ready by the end of 2005. Section 5 introduces the discussion on firm R&D outsourcing to RI in materials, by showing the major areas of research and technological competencies of Brazilian materials researchers and RI. Moreover, it presentes a broad picture of R&D outsourcing by various industrial sectors, including the Brazilian auto industry. It is shown that the frequency of outsourcing contracts is larger than usually acknowledged. The issue is rather the continuity and content of such interaction than the quantity of links. Section 6 focuses on the outsourcing R&D contracts and joint projects between suppliers and assenblers,on the one hand, and RI, on the other. The major finding is that the typical outsourced R&D contract takes from one to two years and aims at what is called in this paper advanced engineering (product or process oriented). Many contract developments are related to the solution of problems posed by the adaptation and or improvement of imported

[4] Data was collected in 2004 by means of a structured questionnaire sent to approximately 70 research groups, out of which we have obtained about 40 replies. Replies have been complemented with interviews with researchers in 25 cases.

technologies which require knowledge which is beyond the capabilities of firms' R&D personnel. Nevertheless, in particular areas of research, such as biomaterials, firms are showing increased interest in establishing longer term joint research projects. Section 7 closes the paper with some reflections on the implications for technology policies.

2. Recent developments in R&D in the automotive sector in Brazil

As much as in other business areas, an important change brought about by the internationalization of the automotive industry has been the global organization and integration of R&D. This process has already gone beyond the economic frontier of Triad countries (US, Europe and Japan) and reached emerging economies. An evidence of it is the fact that Brazilian subsidiaries of multinational assemblers and suppliers have been enlarging R&D mandates in Brazil and stepping-up their product-related technological activities. These have been concentrated mainly on platform adaptations to local conditions (tropicalization) and, to a lesser extent, on the development of derivatives from global platform to suit local demand requirements (Quadros and Queiroz, 2001; Consoni & Quadros, 2003; Dias, 2003; Consoni, 2004).

Yet, at the level of the individual firm, trajectories have varied considerably and evolved sometimes in a rather hesitating way (Consoni, 2004). On the one hand, some assemblers have adopted strictly centralised product strategies, in which technological activities have been developed at headquarters or subsidiaries abroad. On the other hand, the recent experience of other assembler subsidiaries and their accumulated design competencies suggest that they are becoming partners to their headquarters in global product development. Such decentralised product strategy has been associated with product policies which are oriented towards local/regional market needs. It is based on a concept of organisation in which product development functions of assemblers (and some of their suppliers) are dispersed according to regional spaces, which are inter-related but keep a certain degree of autonomy. Today all major assemblers, which are long established in Brazil – Fiat, Ford, GM and VW - have adopted decentralised product strategies, although adopting the concept of global platform. They have experienced the expansion and diversification of development product activities and have been strongly engaged in designing regional derivatives from global platforms. Such strategy has implied an enlargement in the Brazilian engineering capabilities, increasing graduated professionals employed in R&D (technical staff) and improving local technological facilities with investment in laboratories in Brazil. Increase in local PD capabilities has also induced headquarters to outplace demand for certain global product developments. The GM Meriva and the VW Fox illustrate this point. These are products designed by Brazilian engineers for both developed and developing countries. The adoption of decentralised PD strategies by the major players in the Brazilian market has contributed to increase the size and expand the scope of the R&D carried out by such players[5].

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 tropicalization and the design of regional (and global) derivatives has been performed by multinational and national suppliers of auto-parts in Brazil. Moreover, global suppliers like Eaton and Bosch have gone beyond in the process of regional specialization of Brazilian subsidiaries, by raising them to the status of global Centres of Excellence for certain types of

[5] For more details about the strategies followed by car makers in Brazil, see: Quadros and Queiroz (2001), Consoni and Quadros (2003) and Consoni, (2004).

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 1.600 cc (Quintão and Quadros, 2005).

While this tendency suggests that some Brazilian assembler product engineering areas are about to increase status in the global organisation of PD and that some Brazilian multinational suppliers have already undergone such upgrading, technological research activities in Brazilian subsidiaries are scarce and mostly related to specific local demands of PD. There is no formal organizational place (organizational units, competencies and mandates) meant to carry out internal technological research, that is, the exploration of new technological solutions and applications, which require longer time than that of the product development cycle. The largest part of new technological knowledge adopted by assemblers and suppliers in Brazil is transferred from major R&D units located at the headquarters and/or developed at other country subsidiaries, which continue to be the major source of technology knowledge and information.

This does not mean that the development technological innovations is completely absent in Brazilian subsidiaries. New product projects require the search for solutions to local problems posed by the development and adaptation of derivatives. Such solutions have been usually developed internally by the product and process engineering areas of the Brazilian assembler and supplier subsidiaries, as quasi-immediately-applicable technological solutions. It means that new technology knowledge is originated in the needs of local PD. This is why such new technology projects are short, focused on product applications and are organized as part of the PD cycle (instead of becoming organizationally distinct, separated from PD projects). They refer to the process of learning and accumulation of local-related knowledge, which is translated into product/process improvements but is not a priority (in terms of research agenda and intellectual property) for major R&D centres.

Such technology development projects mostly focus on knowledge niches, which are important for local PD and tropicalization in the following areas:
Fuels - development of materials (plastics, alloys) and powertrain components suited to the use of ethanol as fuel or as a component of petrol-based fuel. Recently, Brazilian subsidiaries of assemblers and suppliers have co-designed the so-called flex-fuel system, which makes possible that engines run economically adapted to any mix proportion of petrol and ethanol;
Materials - assemblers and suppliers' materials labs are mostly oriented to research on resistance to oxidation, particularly regarding corrosion. The materials lab also supports R&D on materials replacement and solutions aimed at reducing the cost of entry level vehicles;
Engines - Due to the large specialisation of Brazilian market in consume of popular car, these assemblers have developed competence in the design of small and efficient engines (up to 1.000cc.) which are related to the design of subcompact vehicles. The focus in engine research and development has been the improvement of low powered engines with substantially greater power than the previous generation of small engines;
Suspension - development of more robust suspension modules in order to bear bad road conditions; some suppliers have developed global technological competencies in this area.

In addition to technology development, which is embedded in internal PD projects, incumbent assemblers and auto-parts suppliers have engaged in cooperative and outsourcing technological projects with Brazilian RIs. This is an incipient but growing tendency and suppliers are more inclined to do so than assemblers. This is the subject of the remaining of this paper.

3. Outsourcing and research partnership between manufacturing firms and RI in Brazil

Global firms whose competitive strategy is strongly based on technological innovation and R&D performance have been increasing both R&D outsourcing and partnerships. This is related not only to seeking cost and risk minimization, but also as a strategy to tap technological knowledge and opportunities, which are complementary to their own competencies (UNCTAD 2002). Such partnerships may be organized in different forms of contract (alliances, cooperative research, co-development) with distinctive partners (competitors, suppliers. clients, RIs) (Tidd et al., 2001).

Before moving to examining the nature and the qualitative aspects of R&D outsourcing in the Brazilian automotive industry, in this section we seek to put it in perspective, by comparing quantitative indicators of R&D outsourcing and technological cooperation in the auto industry with other sectors. The section draws on data produced by the Pintec 2000, the first experience of a national innovation survey based on the Oslo Manual (IBGE, 2002; OCDE, 1997).

A simple descriptive tabulation of the Pintec data on R&D outsourcing and technological cooperation by sectors in the Brazilian manufacturing industry is sufficient to reveal that while the automotive industry is very timid in initiating technological cooperation with RI, it is nevertheless among the leading industries as regards indicators of R&D outsourcing. To be sure, it is worth reminding that the concept of technological cooperation adopted in Pintec, in line with the Community Innovation Surveys, requires an active participation of the firm in joint projects with partners, either R&D or other innovation activity-related projects. The outsourcing of R&D services to other organizations without an active collaboration of the contractor is not considered cooperation.

Table 3.1 shows indicators of technological cooperation in the Brazilian automotive industry and in the industrial sectors that present the highest scores as regards assessing the importance of cooperation with RI. Overall, partnership for research cooperation between industry and RI is significantly low in Brazil. Only 1.5% of innovating firms (which represent 32% of the population of industrial firms investigated by Pintec) have considered that cooperation with RI is important. The leading sectors in cooperation with universities and other RI are technology intensive sectors, such as instrumentation and automation equipment and computers and office machines. These sectors are considerably more integrated to local S&T institutions, both funding agencies and research performing agencies, than others. Other sectors, such as chemicals, metallurgy and electrical machinery, which are intermediate in terms of technological intensity, are also intermediate in terms of technological cooperation with RI in Brazil. The automotive industry is in the lower end in terms of giving importance to technological cooperation with RI. In contrast, it attributes high importance to clients, other firms in the group (meaning headquarters) and, to a lesser extent, to suppliers as partners in technological cooperation.

Table 3.1 - Share of innovative firms marking high importance to technological cooperation by type of cooperation partner in selected industrial sectors Brazil: 2000 (%)

Industrial Sector	Clients	Suppliers	Other firm in the same group	Universities and other RI	Innovative firms (N)
Instrumentation and automat.	3.4	5.3	2.9	7.0	416
TI and business machines	15.6	13.8	7.3	6.4	109
Chemicals	5.6	6.4	6.7	3.6	1393
Rubber and plastics	7.2	7.2	1.0	3.3	1678
Metallurgy	6.1	3.8	2.8	3.3	395
Oil and alcohol refining	9.2	3.1	7.7	3.1	65
Pulp and paper	6.6	3.3	2.4	2.4	334
Electrical machinery	3.7	3.9	2.9	1.9	699
Automotive	7.5	4.5	7.5	0.2	638
Manufacturing industry	3.8	4.3	1.9	1.5	22401

Source: IBGE, Pesquisa Industrial – Inovação Tecnológica, 2000.

In contrast with the situation commented above, the comparative performance of the Brazilian auto industry in outsourcing R&D presents a more pronounced profile (Table 3.2). Firstly, it ranks third in terms of the absolute value of R&D outsourced (US$ 41 million) and second as regards the average value of outsourcing per firm (US$ 0.78 million). However, if the auto-parts sector is subtracted from total automotive, the average outlay in external R&D per firm in the automotive industry (US$ 1.45 million) is the largest in the Brazilian manufacturing industry. It is only matched by the average outlay in R&D outsourcing made by the telecom industry, which benefits from a fiscal incentive law for IT sectors (Lei de Informática). The law requires that firms outsource a minimum share of its R&D spending in order to qualify for the incentives. The automotive industry does not benefit from similar incentives. Second, the indicator of the last column reveal that the average spending in external R&D per performing firm represents 80% of the average spending in internal R&D per performing firm and is also among the largest[6]. However, in this particular aspect, the auto-parts industry is more prominent, that is, it relatively relies more in outsourced R&D, than assemblers and other firms of the group (such as bus and truck body builders) do.

Table 3.2 - Internal R&D and Outsourced R&D outlay per firm in selected industrial sectors Brazil: 2000 (current million US dollars)

Industrial Sector (ISIC 2/3 digit)	Internal R&D (total)	Internal R&D per firm (A)	Outsourced R&D (total)	Outsourced R&D per firm (B)	B/A
Automotive - autoparts	211	3.29	30	1.45	0.4
Autoparts	47	0.25	11	0.34	1.4
Total automotive	258	1.00	41	0.78	0.8
Mechanical Machiney	186	0.20	11	0.08	0.4
Electrical Machinery	142	0.37	21	0.46	1.2
Chemicals	288	0.33	69	0.38	1.2
Telecom	199	1.80	74	1.42	0.8
Other Trnsport Equipment	142	1.24	1	0.10	0.1
Manufacturing Industry	2028	0.28	340	0.20	0.7

Source: IBGE, Pesquisa Industrial - Inovação Tecnológica 2000.

[6] Note that the group of firms performing internal R&D is different from and larger than the group of firms outsourcing R&D.

Even though the innovation survey data indicate that the auto industry in Brazil presents a considerable expenditure in outsourcing R&D (for the Brazilian standard), these figures do not mean that RI and research are the main destination of such resources. Indeed, the Pintec survey does not collect information on what are the institutions to which firms outplace R&D. In the case of the automotive industry, it is known that both assemblers and auto-parts producers largely rely on engineering service firms in order to complement internal product and process development activity. This is possibly what accounts for the largest share of R&D outsourcing in the Brazilian automobile industry. Certainly an unknown amount of such outsourcing is likely to be placed to Brazilian RI. However, in order to understand whether the auto industry outplaces research and development to Brazilian RI, and what is the nature of such outsourcing, another type of investigation is required, as is shown in the following sections.

4. Methodology and research strategy

This paper seeks to investigate whether and how research on automotive technologies in Brazil has been relying on outsourcing and/or cooperative research between assemblers and auto-parts producers and RI (universities and public labs). It draws on data collected trough an on-going and joint research project involving Renault and Unicamp. The objective of the project is mapping out technological capabilities and opportunities applicable to the automotive industry in Brazilian RI. The project was commissioned by the Research Strategy and International Networks division of Renault to the Research Group on Firms and Innovation (Gempi) of Unicamp. It started in March 2004 and is planned to present final results in October 2005. The aim of the project is to identify and characterize major scientists and research groups, who work in Brazilian research institutions on technologies (at least potentially) applicable to the automobile industry. The project intends to look not only for researchers' competencies, but also to identify possible technological opportunities they have developed in their work.

The construct capabilities/competencies adopted in the project has been operationalized by means of a wide scope of indicators, both of inputs (researchers' background, size of research group, grants obtained, lab facilities, and so on) and outputs (patents, publications and major scientific and technological achievements). This decision guided the elaboration of research tools that are described below. Another important aspect is that the interest of the project is not only to identify competencies applicable to the automobile industry, but particularly the ones among those which were willing to engage in research partnership with the industry. This is why it was so important that the characterization also took into account the partnership background of the researcher/research group.

Another early and important methodological decision was to take research groups (RG) as the unity of research and, therefore, the smallest identifiable part of research to be considered in the project. RG here refers to the organized unit of research involving one or two senior scientists and their students and associate researchers. RG do not require necessarily an S&T certification, as the one the Brazilian CNPq grants to the groups registered in its directorate of research groups. What makes a RG is rather its capability to mobilize competencies and resources in a scale that raises substantially the productivity of research. Adopting RG as the unit investigated in the project has facilitated both the identification and the characterization of competencies.

Given these objectives and approach to capabilities and the unit of analysis, the following

challenges were 1. Finding and selecting the relevant RG to be surveyed and 2. To collect information. As to the first point, it has been adopted a mix of techniques comprising searches in databases (mainly CNPq's Lattes database) and qualified websites, interviews with experts in the respective technological fields to be investigated and the technique of snowball sampling, in this case, snowball of peers (Atkinson and Flint 2001).

The design of the questionnaire implied a choice of issues to be investigated and a structure and hierarchy of information to be collected. The following issues or major aspects of investigation were defined in order to guide the design of a questionnaire (and the structure of the database):

- To characterize the main features of the RG, in order to be able to measure its academic excellence and importance;
- To identify the major technological and scientific advances/attainments of the group;
- To identify the applicability of RG's competences and attainments in technologies applicable to the automobile industry;
- To map RG's experience in technological cooperation with corporations (in all sorts of areas and businesses) and its willingness to engage in such cooperation.

The project has advanced in steps or phases, which have been divided according to major technology fields. The first step, which also served as basis for designing and testing methodology, focused on the vast field of materials. The following steps have been power-trains and fuels and alternative sources of technology. These will be followed by manufacturing technologies, modeling and simulation, on-board electronics and ergonomics.

The following sections of the paper are based on the results of the first step of the project. Thus they draw on data on cooperative research and outsourcing between RI's research groups and corporations from all industrial sectors (not only the automotive), in the field of materials technologies. Data refer to 37 research groups in Brazilian universities and research labs, most of them working on frontier technological issues in disciplines such as Chemistry, Physics, and Materials, Chemical, Mechanical and Metallurgical Engineering. Such groups belong to 15 institutions, including all Brazilian prestigious universities and labs working on materials.

5. Main technological achievements of research in materials in Brazil and applications by industry

One of the important results from the mapping out is that Brazilian research institutions have accumulated significant knowledge and research experience in the relevant technologies. The study pointed out the applicability of research group's competencies and technological attainments applicable to the automobile industry. Moreover, there are important results in several areas of technological research positioned on the knowledge frontier. Table 5.1 indicates the frequency of the investigated research groups according to technological domain.

Often research groups have attained competencies in more than one technology domain. The common knowledge basis of some technological domains facilitates such diversification within research groups. The highest frequency is in "Composites based in biomaterials (natural fibers), Biodegradable, Ceramic composites", with 23 mapped research groups. As regards such domain, it is worth to illustrate with the case of polymeric composites reinforced with vegetal fiber (curauá fiber). Curauá (Ananas erectifolius) is an Amazon plant from the

pineapple family. The curauá dry fiber has great mechanical resistance, which makes it capable to bear very high strain, in spite of its not being a thick fiber. Such property has made curauá a natural substitute for fiberglass in the reinforcement of polymeric composites. When mixed to other polypropylene-based materials, such as blanket and carpet rests from the textile industry, it becomes a composite, which has great potential of use in the automobile industry. Assemblers' interest in introducing new materials that are more environmentally friendly, at the end of the car's working life, continues to grow. Moreover, there is the need to lower vehicle weight and make it lighter.

The domain "Corrosion, Fatigue, Electrodeposition of metals and alloys, Surface treatment, Thermal treatment and quenching" presents the second highest frequency, with 17 RG. These technologies are associated with resolution of problems such as vehicle wearing, materials degradation, measuring fracture tenacity in deformation situations, among others. Technologies related with steel and aluminum alloys also concentrate many research groups and competencies in Brazilian RI, which seems to be in line with the size and proportion of the metallurgy industry in Brazil.

It is worth to add that the low group frequency in Materials Recycling technology does not represent a limited concern with renewable materials in Brazilian RI. The result is due to the methodological for classification, which focused the main RG technological specialization. This means that Materials Recycling technology competencies are included in groups classified in other domains. For instance, in Steel and Aluminium Alloys, we identified the development of an alternative alloy that uses aluminium with non-conventional properties and turn the engine completely recyclable. In Corrosion, there is the development of PHB (Poly Hydroxide of Butyrate), which is a biodegradable polymer. The PHB is handled either separately (isolated) or mixed with modifiers (sugarcane, coconut, sizal, wood and others). The main advance, in relation to traditional polymers, is the use of modified polypropylene able to substitute the engineering material. In Biomaterials, there is the development of a polymer blend with granulated natural fiber to replace fiberglass and the development of a fiber reinforced composite, which can be used in injection processes.

Table 5.1 - Materials Science research group frequency by technological domain - 2004

Technology	Group Frequency
Composites based in biomaterials (natural fibers), Biodegradable, Ceramic composites	23
Corrosion, Fatigue, Electrodeposition of metals and alloys, Surface treatment, Thermal treatment and quenching	17
Steel alloys, Shape memory steels	7
Aluminum alloys, Titanium alloys, Niobium alloys	7
Adhesives, Performance elastomers	5
Modeling of Materials Processing	5
Nanocomposites	4
Polymer aging, Silicon polymer	4
Amorphous Materials	3
Tribology	2
Impact (Shock absorption)	2

Source: fieldwork, project Renault/Unicamp

Results of the survey of materials RG also revealed that the frequency of contacts and contracts between firms and RG/RI, which are related to the outsourcing of R&D and services, is larger than usually acknowledged (Table 5.2) and even more so in regard to the automotive industry. As most of these contracts have been funded by firms' resources (and not by government sources), they may prefer to keep this type of information non-disclosed. Certainly, the fact that the focus of our research and of the methodology of peer recommendation was the applicability of competencies and technologies to the auto industry has introduced a major bias in results in favour of contracts with the auto industry. This is why we cannot compare frequencies between sectors in Table 5.2. However, it is interesting to notice that frequencies are relatively high in industries other than the automobile, such as the steel and aluminium, the chemical, the aircraft and the food industries. The fragility in the links between firms and RI seems to be rather in the intensity and continuity of the link than in the frequency of links.

The first sign of the latter point is that the overall frequency of services contracts is much higher than that of research contracts. Secondly, the continuity of research funded by a firm (except for Petrobrás) is rare. There are few contracts for research continuing beyond two years. Moreover, in the case of assemblers, we have spotted at least three cases of 2/3 year research projects which have been discontinued (and have not rendered applications). This issue is further discussed in the next section.

As regards the distribution of frequency of RG contracts by science disciplines, almost half of them are classified in the Materials Engineering and Metallurgy area (51.4%). The other knowledge areas are: Chemistry (16.2%); Physics (13.5%); Mechanical Engineering (10.8%); and Chemical Engineering (8.1%). Again, the focus of the snow ball sampling on identifying researchers/research groups whose achievements and capabilities, in Materials Technology, were potentially applicable to the automotive industry, contributed to the much larger participation of researchers in Materials Science/Engineering. It is worth to add that outsourced research is concentrated mainly in the same fields in which there are considerable research competencies in Brazil, and which have been emphasized in Table 5.1: composites and polymers, metal alloys and biomaterials.

Table 5.2 - Frequency of research group's contracts/projects related to R&D and technological services outsourced by industrial firms, by discipline and type of contract[1]

Industrial Sector	Chemistry		Chemical Engineering		Physics		Mechanical Engineering		Materials Engineering Metallurgy		Total	
	S[2]	R[2]	S	R	S	R	S	R	S	R	S	R
Automotive - autoparts	1	4	1	-	1	-	1	1	10	4	14	9
Automotive - assemblers	1	1	-	-	-	-	1	-	4	2	6	3
Metallurgy (Steel/ Aluminium)	-	1	3	2	-	-	-	1	10	4	13	8
Chemical	3	5	1	1	-	-	-	-	4	2	8	8
Oil refining	-	2	1	1	-	-	-	-	-	2	1	5
Aircraft	-	-	-	-	-	-	-	-	1	2	1	2
Telecommunication	-	1	-	-	-	1	-	-	-	-	-	2
Food	3	-	1	1	-	-	-	-	--	1	4	2
Energy	-	1	-	-	-	-	-	-	-	-	-	1
Instruments (Medical)	1	-	-	-	1	-	-	-	1	1	3	1
Mechanical	-	-	-	-	-	1	-	-	1	-	1	1
Metallurgical/ Casting	-	-	1	-	-	-	-	-	-	1	1	1
Pulp and paper	1	-	-	-	-	-	-	-	-	1	1	1
Textile	1	-	2	1	-	-	-	-	-	-	3	1
Hygiene and cleaning	-	-	-	-	-	-	-	-	1	-	1	-
Electronic	-	-	-	-	-	-	-	-	1	-	1	-
Computer Science	1	-	-	-	-	-	-	-	-	-	1	-
Sugar & Alcohol	1	-	-	-	-	-	-	-	1		2	-
Total	**13**	**15**	**10**	**6**	**2**	**2**	**2**	**2**	**34**	**20**	**61**	**45**

Source: Materials Database

1. Numbers refer to research group frequency and not the number of firms.
2. R: research; S: Service

6. Outsourcing of R&D and services by firms in the automobile industry

As mentioned in the previous section, the automobile industry presents a considerable frequency of research and service outsourcing contracts with Brazilian RG in the area of materials. Moreover, these are more frequent in services than in research. In this section, we present more detailed data regarding such outsourcings and analyse their implications.

Even tough the number of contracts involving assemblers is smaller than the frequency among auto-parts firms, the assemblers' experience is quite revealing. Indeed, longer term and less immediately applicable research outsourced by assemblers have been rare and entirely related to experiments with biomaterials (Table 6.1). However, it is interesting to note that services refer rather to advanced engineering services or developments, than short term outplacement of small services, like testing. Two examples underline this argument: the development of safety under-rides for trucks, which is a major line of development of a research group at Unicamp and the development of a corrosion inhibitor powder.

Table 6.1 - Research/Development contracts outsourced by assemblers to Brazilian RG

Firm	Technology/Content of project	Functional area	Type of project
GMB	Composites based on biomaterials	Weight reduction; environment	Research (2 years)
GMB	Simulation of mechanical fracture and fatigue	Durability	Service (2 years)
GMB	Under-ride truck guards	Safety	Service (2 years)
VWB	Carburator corrosion	Durability	Service
VWB	Biodegradable polymer	Environment	Research (3 years)
VWB	Corrosion inhibitor	Durability	Service
DCB	Composites based on biomaterials	Weight reduction; environment	Research
DCB	Underride truck guards	Safety	Service (2 years)

Source: Project Renault/Unicamp: Materials Databese

The diversity of contracts, areas of outsourcing and even in research outsourcing presents higher profile as regards suppliers (Table 6.2). Starting with the latter point, research outsourcing from suppliers goes beyond biomaterials, to include the development of new metal alloys, major changes in manufacturing processes and corrosion control technologies. There two cases of outsourced research which have received support fromBrazilian S&T funds: the Pematech-Unesp project on biomaterials and the Agrostahl-USP project on new Ni alloys. These are recent projects which are revealing of an emerging good-will and interest in Brazilian automobile firms and RI to increase outsourcing (if not technologiclcooperation). In both caeses,project are supported by new Brazilian S&T institutions and funds (eg.the FundoVerde-amarelo) which have given priority to technological, industrialapplied research. The caseof Pematech interestingalsobecause it involves an indirectparticipation of VW and the support of Finep, the main federalagency for funding applied researchin firms.Pematech has developed curauá fiber based fillings for the interior of the VW Fox. The application technology and fiber production requirements led Pematech to establish a patrneship with a major research group at Unesp (in the state of São Paulo),which specialises in naturalfiber agriculture and industrialapplication.The project received considerable support from Finep, to fund the university part of the development, in addition to the investment made by Pematech.

Table 6.2 - Research/Development contracts outsourced by suppliers to Brazilian RI

Firm	Technology/Content of project	Functional area	Type of project
Eaton	Ultrafine grain steel - application	Weight reduction	Service
Eaton	Plasma nitritation in metals	Durability	Service
Eaton	Adhesive development	Durability	Service
Pirelli	Modification in copper wire manufaturing	Weight reduction,cost	Research (2 yeras)
Pirelli	Analysis ofcorrosion in components	Durability	Service
Agrostahl	New NiCrAlC alloys	Durability	Research (2 years)
Agrostahl	Surface treatment – friction reduction	Durability,cost	Service
Pematech	Biomaterial composite development	Environment, weight reduction	Research (2 years)
Teksid	Simulation of mechanical fatigue-fracture	Durability	Service
Tupy-Fras Le	Characterization of wearing factors (metals)	Durability	Service
Sifco	Ultrafine grain steel - application	Weight reduction	Service
Mangels	Quality in casting	Cost, durability	Service
Non-disclosed	Equipment development forcorrosion control	Durability	Research (3 years)
Mahle-Cofap	Analysis of corrosion	Durability	Service
Toro	Biomaterialcomposite development	Environment,weight reduction	Research
Lord	Adhesives for alluminium	Safety	Service
Ourofino	Manufacturing of under-ride truck guard	Safety	Service
Non-disclosed	Metal casting and solidification development	Weight reduction	Service

Source: Project Renault-Unicamp:Materials Database

Service outsourcing contracts to Brazilian RI also present larger diversity amongst suppliers than assemblers. It is important to emphasise, again, that services here are generally related to what could be called an advanced engineering, rather than short term, testing-like services. The typical situation is one in which the adapation or even an improvement development in a given component requires materials technology knowledge, which is beyond the capabilities of the firm's Brazilian product development team (usually in a multinational corporation). Thus, in such contracts, Brazilian RI work as if it were a replacement for the central R&D corporation lab, supplying solutions to the Brazilian engineering team. This is so for various

reasons, some of them have been discussed recently by the authors with supplier PD engineers. First, there are specificities of applications, cost parameters, and implications of distict wheather and temperature in Brazil, all of them with implications for materials technology, which make it difficult and costly for central labs to provide prompt and efficient solutions. Secondly,usually central labs are too busy attending the corporation's priorities and can not afford dedicating the time the Brazilian subsidiary requires. In the case of Brazilian national suppliers, the explanation issimilar,with the difference that there is no central lab to turn to and problems arise either from the adaptation of licensed technologies or from new technology development, as in the case of Pematech.

7. Conclusions

Although the research reported here has not focused on policy measures, it seems to underline that there is ground for substantial increase in research cooperation (at least in research outsourcing) between firms and RI in the Brazilian automobile industry. There is a critical mass of firms and of engineering activities in them, which are interested and mature for such cooperation, whereas Brazilian RI have accumulated significant knowledge and research experience in the relevant technologies. Thus, governments and Brazilian industrial policy can play an important role in promoting and intensifying technological activities performed locally by RI and the Brazilian industry. As regards the current framework for industrial policy in Brazil, our findings suggest that a more down-to-the-earth approach would enlarge the sectoral focus of industrial policy support beyond high-tech and capital goods segments, and consider areas of business which are mature for increasing investment in R&D.

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