Cooperation between France and Venezuela[1] in the field of catalysis

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International scientific cooperation takes many different forms. Although states lay down policies to establish bilateral or multilateral institutional arrangements among themselves, scientific activity itself creates links between scientific institutions and laboratories as a result of the contacts established between individual researchers for specific purposes. Scientific collaboration has become the norm in modern scientific practice (Hicks & Katz 1996). However, as well as being necessary, international scientific collaboration inevitably operates according to rules that are different from those governing research that is carried out individually or without institutional collaboration. There has been much discussion of the factors determining this growing international collaboration, which has been confirmed empirically by analysis of the co-authorship of scientific articles (National Science Board 2000, OST 1999). The point has often been made that scientific collaboration is a response to geopolitical strategies and that increasing economic integration inevitably leads in turn to greater scientific integration (Arvanitis *et al.* 1995, Schott 1993). Researchers from some developing countries more than others take advantage of international collaboration to attract attention to their work and to gain opportunities for professional and scientific advancement. However, all researchers now know how to use and actively promote schemes of collaboration. A large number of institutional schemes have been tried out in the context of so-called policies of international cooperation, a term that covers the relations of developed countries with developing countries. Some countries, such as France, UK, Sweden, and Denmark, have placed particular emphasis on collaboration with developing countries (Gaillard 1999).

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It is our intention to study the arrangements for cooperation between France and Venezuela by means of micro-analysis rather than bibliometric analysis, which is normally used for such purposes (Lewison *et al.*, 1993). We believe that replacing macroscopic analysis of countries by microscopic analysis of specific exchanges among universities and laboratories makes for a better grasp of movements of scientific findings and of the position that a country occupies in a particular scientific field. Furthermore, we believe that the way scientific collaboration responds to cultural variables and influences can only be observed through qualitative analysis, which allows us to examine the factors that determine communication between scientists as quantitative indicators do not (Edge 1979).

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The PCP scheme: an original example

In this article we shall examine a programme of collaboration between university scientists from France and Venezuela, known as the Postgraduate Cooperation Programme (PCP). The programme links researchers, laboratories, and postgraduate teaching programmes through bilateral agreements between the two countries. It involves periods of study abroad by students, generally working for a Ph.D., who are enrolled in a university in their own country, but who spend some of their time in a partner university in the other country where they do work related to their doctoral thesis (Ambassade de France/CONICIT-Venezuela 1999). Such exchanges also involve short stays by researchers from the laboratories in the partner country that are taking part in the programmes. This is a new kind of arrangement that was tried out in Colombia and Venezuela before being extended to Mexico. Its particular originality from an institutional point of view, as we shall see below, lies in its involvement of industrialists. The principles of the PCP are: (a) the establishment of networks of top-class laboratories in both countries; (b) long-term programme planning (four years) so as to enable theses to be completed on a time-sharing basis; (c) funding of the research by the industrial partners and of the costs of moving by the institutions of the two countries on an equal basis; and (d) joint determination of the objectives by the industries and the laboratories taking part.

At the beginning of the PCP, during the years from 1970 to 1980, a combination of factors occurred, some of which were more problematic than others. As far as university cooperation was concerned, there do not appear to have been any major problems, since this involved more or less equal exchanges of knowledge, techniques, and material between 'equals' or, at least, between teacher and student. However, that changed when state bodies became involved – the CNRS and the French Ministry of Foreign Affairs and large companies. In this institutional context, which goes beyond the strictly university framework, things become complicated because they involve 'practical political problems' as well as scientific cooperation. However, it is precisely industrial support for the funding of research and the application of its findings that probably constitutes the most innovative aspect of this programme.

One view of this triangular relationship between researchers, government, and industry is to emphasise linkages with the productive sector. In the programme's early years, this approach, which is more familiar to engineers than to basic scientists, proved rather difficult to accept. Some of the French researchers interviewed felt that the Government and French companies were hoping that they would act as a bridgehead for French industry, a view with which those who had been at university in the years following the events of May 1968 in France did not always feel very comfortable. Their opinion was shared in Venezuela by the researchers who were working in collaboration with them. At one point problems even arose in the collaboration between researchers when, following the nationalisation of the oil industry, the public company specialising in technology in Venezuela, INTEVEP, began to assert its independence in such fields as intellectual property more energetically, provoking the French Petroleum Institute (IFP) to break off relations and withdraw from the country. Researchers from IFP were no longer able to collaborate with INTEVEP and the universities that had helped to train a whole generation of researchers in Venezuela were unable to continue collaborating. The French academics requested the CNRS to continue the relationship without reference to industry, since they did not wish to lose contact with well qualified people who had been their students. On the other hand, some university researchers from Venezuela took advantage of the tradition of exchanges to maximise the opportunities provided by French technical cooperation mechanisms, when, at the beginning of the 1980s, the alternatives of Venezuelan government scholarships were closed to them as a result of the economic crisis in their own country.

Although it was not easy to obtain industrial support for an academic programme, the situation changed in time and more sustained interest was shown by small and medium-sized enterprises. In 1998 the terms of the programme were renegotiated and participation by the productive sector is now required as a basic element if proposed activi-

ties are to be approved by the funding agencies responsible (CONICIT and the French Ministry of Foreign Affairs), in order that the knowledge produced may be of use to society. Large industrial groups have also participated, and the basic support provided by groups in the oil industry such as Elf, Total and INTEVEP facilitated the involvement of a wide range of other large companies such as Lyonnaise des Eaux, EDF, Peugeot, Danone, Akzo-Nobel, Générale Sucrière, and Thomson–CSF. In this way, the PCPs will help to bring French companies and areas of industry into contact with the Venezuelan market. The effects may well be diffuse and will not receive as much publicity as the institutions associated would like. However, industrial funding is approaching that of the universities, it having always been an objective that the PCPs should operate on this basis. CONICIT's share of the funding has been quite high in recent years as a result of the large number of Venezuelan experts mobilised by these various programmes.

The French researchers interviewed maintain that the initiative for a PCP on catalysis came from Venezuela, and that they entered into collaboration but did not initiate it. That raises a number of questions for us. Is that the real story? Why did so many people in Venezuela choose to study catalysis in France? Why don't more Venezuelan students go to Spain where there is also a school of catalysis, instead of to France? Is it because of the influence of French research in that field? Or because the French have technology and equipment that they want to sell and therefore offer better opportunities for collaboration? Is the PCP a way of publicising French science? Why does it take the form that it does? Could it be that the definition and organisation of the programme corresponds to the French rationalist state model? Why was the thrust so strong in catalysis? Because of the standard of catalysis in France? Because of the standard of catalysis in Venezuela? Because of the convergence of interest of the chemists involved in both countries?

Catalysis

The pluridisciplinary nature of catalysis, lying at the junction of several different disciplines such as coordination chemistry, surface chemistry, chemical engineering, the chemistry of solids, organic chemistry, electrochemistry, geochemistry, etc., reflects its central position in modern chemistry, although this same pluridisciplinarity also has its downside, since it means that researchers are working in different laboratories and that their findings are reported in a variety of different journals or congresses, without there being any single event that brings the whole community together, or any journal offering a synthesis of all the different contributions.

It is commonly said that catalysis is a chemical process involving the use of a substance – the catalyst – that increases the speed of reaction without being consumed itself in the course of the reaction. This is the classic definition, although over a period of time the concept has changed, mainly with regard to the content and position of the catalyst (Ceruti 1999). The shift from seeing the catalyst as a substance to the current view of it as a material corresponds not only to the new, dominant position of the science of materials, but also to laboratory formation and practice. Organic chemistry works with substances, while physical chemistry would, on the contrary, be more comfortable with a material. The change of emphasis in the definitions of catalysts is therefore linked to a change in working practices and, above all, industrial practices.

We are probably now witnessing a fundamental redefinition of disciplines, including the more 'traditional' areas of heterogeneous metallic catalysis in petrochemistry and refining. Researchers who lived and worked during the period following the invention of the Ziegler–Natta polymerisation catalysts do not realise what a radical change this was. However, those researchers who have close links with industry are under increasing pressure to obtain 'scientific' answers to economic problems, such as, for example, the stability of catalysts, since the regeneration of catalysts costs $7 billion a year (J. Barbier, personal communication).

The relation of the academic scientific community to industry is the main issue examined in this study. Catalysis is studied at university as a result of pressure to reduce the costs

of the empirical approach in industry.[2] The university researcher must keep a close eye on the problems of industry: "the preparation of catalysts having good industrial performance can show insurmountable difficulties even for catalytic researchers, if not skilled in manufacturing practice. This is mainly because even *small changes* in manufacturing procedure may have *large effects* on catalytic properties" (Ceruti 1999). Thus, we are looking here at a scientific environment which is both dependent on industry but also in a strong position, since it can contribute to the profitability of industrial processes. The interesting research topics are often suggested by industry or spring from an approach that has immediate repercussions for industry. This close relationship defines both the limits of what can be done in the university laboratory and also its possibilities.[3] The discovery of a catalyst for a reaction in the laboratory and its improvement and adaptation for large scale manufacturing processes are generally followed by the almost immediate acquisition of negotiable patents, even in the case of processes which may, in the immediate circumstances surrounding their appearance, offer little prospect of economic return.

They are of enormous importance today since the profitability and very existence of all the basic chemical and/or pharmaceutical industries rely heavily on the proper operation of catalytic processes in as many of the stages of production as possible. It is this aspect that has become the dominant factor in recent times (and will become even more so in the future), in view of the increasingly restrictive international standards imposed by society in response to the levels of environmental pollution of industrial origin that are regarded as acceptable. Thus, although at the beginning the academic community worked on catalysis in order to investigate the possibility of making kinetically available a greater number of thermodynamically feasible processes and/or in order to try out ways of obtaining new products, now that such processes are well established their continued existence and competitiveness are decided in a context in which the selectivity of the process and, therefore, of the catalyst, in terms of the percentage reduction of useless or polluting by-products, plays an increasingly crucial role.

Catalysis in France

Catalysis in France at one time displayed a certain individuality. It is the only country that early on presented a coherent view of catalysis. In the United States of America it is not a separate area of study, but is spread over various disciplines. In France, on the other hand, there has traditionally been a great deal of interaction between groups working within one and the same institution, which could therefore approach problems simultaneously from many different angles. Its origins go back to Paul Sabatier, who from the end of the nineteenth century until his retirement in 1929 established a research and teaching programme in organic chemistry in Toulouse, which was far in advance of Paris, with the foundation of technical institutes in that university that made it possible to establish counterweights in the provinces to the traditional central predominance of Paris within the French scientific community (Nye 1986). His early development, with Senderens, of catalytic hydrogenation at the beginning of the century rapidly found industrial applications. In addition, the North American researcher of Russian origin Vladimir Ipatieff had as disciples in his laboratory at Northwestern University two French researchers – J. E. Germain and M. Prettre – who would become the founders of modern French catalysis and define the identity of the modern French school of catalysis. In the middle of the century, catalysis in France was mainly concentrated in the two schools of catalysis in Lyon and Poitiers.

The Lyon school

Mr Prettre, a physical chemist who decided to take up the study of catalysis, founded the Institute of Catalysis Research (IRC) in Lyon during the 1950s. The kind of catalysis that was characteristic of IRC was more closely linked to the physical chemistry of the catalyst and the characterisation of surfaces, and a more basic and fundamental approach was adopted. For many years IRC was the only institution in France that had all the specialised apparatus required for the different types of catalysis, including that for the definition and identification of catalysts for IFP, etc. According to an experienced observer, Mr Pierre C. Gravelle,

there was increasing competition between IFP and IRC, which was clearly quite healthy. Prettre was succeeded by B. Imelik and then in 1978 the director of the CNRS at that time decided to invite Raymond Maurel to take charge.

The Poitiers school

J. E. Germain began his career at the School of Chemistry in Lyon before going on to the Ipatieff Institute at Northwestern University, where he worked under the supervision of Herman Pines. Back in France, Germain introduced a second school of catalysis at the *Ecole Normale Supérieure* (Paris). Maurel was his disciple and followed him when Germain moved to Lille. Subsequently, Germain was appointed to Poitiers, although when he was still in Lille he had placed his disciples in Strasbourg, Caen and Poitiers. Germain's original studies were in organic chemistry. He focused on the mechanisms of reaction, molecules, and kinetics. The catalysis practised in Poitiers was described to us by some of its exponents as "the poor man's catalysis". It required much less money than research on the definition and description of solids and perhaps for that reason was an interesting model for developing countries. However, the fact was that they subsequently received a high level of funding. Many researchers and enterprises went to Poitiers to work on the characteristics of solids. Industry found it easier to establish links with Germain's school than with Prettre's, since it was working on real molecules in real reactors.

The Louvain school

There was a third school that used these two lines of research as the basis for its own individual approach: the Catholic University of Louvain. During the 1930s a chemical kinetics unit was founded by J. C. Jungers, and this subject area proved to be of great interest for IFP, as did that of the physical chemistry of combustion directed by A. van Tiggelen in the 1960s. These two lines of research made Louvain into a magnet for the IFP. It was even said, as a good-natured joke, that there was no point in applying for a job at IFP if you didn't have a doctorate from Louvain.

The development of catalysis in industry was rather irregular. Work was done on catalysis in all the major industries, but the scientists concerned were working in different industries and there were no recognisable groupings.

Nowadays the overall situation of catalysis in France is more complex than it was in the middle of the century. Everybody does everything. Chemical catalysis or pure chemical catalysis is on the rise. Petroleum catalysis has reached a ceiling, particularly from the scientific point of view. Much industrial catalysis looks more like engineering nowadays. Approximately 50% of the costs of university laboratories are paid by industry and, therefore, much academic research is a response to industrial needs. Specialisation has increased as a result of contracts with industrialists. Whereas 25–30 years ago there was little awareness of chemical catalysis (the domain of organic chemists) and only petroleum catalysis was carried out, nowadays industry knows what questions to ask researchers, who, as a result, can work more closely with industry. Laboratories are familiar with the problems of industry and industrialists themselves also take an interest in chemical catalysis, putting forward research projects that are of interest to researchers.

A recent survey of laboratories and researchers working in the field of catalysis in the public and private sectors in France revealed more than 50 laboratories that had at least one team working in this field, and approximately 850 researchers (Breysse 1998). At the Eleventh International Catalysis Congress in 1996, France was responsible for an estimated 15% of the papers, after the US and Japan, and with the UK close behind in fourth place. However, the Catalysis Division of the French Chemical Society (SFC) had 264 members in 1993, 320 in 1994, 280 in 1995, 294 in 1996, and 324 in 1997, figures that compare with those for Venezuela. The remarks by Jacques Vedrine in his final address as president of the Catalysis Division of the French Chemical Society in 1997, helped to explain these membership figures. According to Vedrine, the French do not like to belong to an association, society, or union: they have the impression that they have been conscripted, and feel they are placing their professional individuality – not to say individualism – in jeopardy. Vedrine stressed in his

TABLE 1. Output on catalysis recorded in the PASCAL database 1996–1998[13]

Country	Publications	Percentage
United States	4,103	21.2
Japan	2,779	14.3
France	2,184	11.3
Germany	1,318	6.8
Russia	946	4.9
United Kingdom	917	4.7
India	652	3.4
Canada	558	2.9
Netherlands	539	2.8
Switzerland	240	1.2
Argentina	180	0.9
Brazil	169	0.9
Australia	162	0.8
Israel	116	0.6
Mexico	108	0.6
Norway	91	0.5
Venezuela	63	0.3
Chile	40	0.2
New Zealand	21	0.1
Colombia	15	0.1
Algeria	15	0.1
Total publications	19,376	100.0

Source: PASCAL database. Compiled by the authors.

farewell address that unity is strength, and that a powerful community can set its own agenda. He drew attention to the fact that the SFC had 10 times fewer members than the Royal Netherlands Chemical Society! He went on to say that when the president of the SFC wishes to enter into discussions with the Germans, the British, or the Dutch on the future of national scientific journals with a view to transforming them into European scientific journals or taking measures to establish a European chemical association (to rival the *American Chemical Society*), the other European countries understandably point to the relatively poor representativity of the SFC (Vedrine 1998).

Table 1 provides an overall view of the distribution of scientific work on catalysis in the world. The US is well in the lead, with almost one article or document out of every five. However, Japan has quite a high number of articles, even though it is not an oil-producing country, and its chemical industry is not as powerful as that of other countries. Activities in some countries, such as the Netherlands, are dominated by one large company (in that case, the Shell research laboratory (Scholten 1994)). In general terms, catalysis research is closely linked with companies, although in France this connection is limited (at least in the field of heterogeneous catalysis) to a few very large companies such as Elf, Total and Renault.

Generally speaking, only a minority of French researchers have links with peripheral countries. This does not seem to be the case in the field of catalysis, probably on account of its connection with the oil industry, and collaboration with some countries has been very close. In some cases, the French have been able to export the institutional model which developed around IFP (to Iran, for example). It has to be said that it is a system that has been successful and which has enabled France to have an oil industry even though it has no oil fields on its territory. A large number of enterprises forming a really innovative system thus came to form around IFP (Furtado 1994). Hence the importance of countries such as China, Russian Federation, Mexico, Argentina, Brazil, and Venezuela in international collaboration involving French catalysis, and the involvement of the leaders in this field in France in the missions and evaluations of the international programmes organised with these countries.

The background to catalysis in Venezuela and the 'French connection'

In Venezuela work on catalysis began in 1964 when a cooperation agreement was signed between the Central University of Venezuela (UCV) and the University of Munich, with a view to developing training and research activities in the School of Chemistry of the faculty of science. Research was just beginning to be developed in the faculty and it was expected that catalysis would be vital for the chemical industry, especially for the refining industry, which for Venezuela, an oil-producing country, was the main industry (although at that time it was still in the hands of foreign concessionaries). This cooperation programme, launched on the initiative of the faculty of science thanks to the contacts established by a young Venezuelan teacher studying at the G.M. Schwab Institute of Physical Chem-

istry in Munich, brought to the country Professor Heinrich Nöller and his collaborator, the Spaniard Paulino Andréu, who at that time was doing postdoctoral studies in Germany. Andréu settled in Venezuela and was involved in most of the subsequent developments in catalysis in the country.

The School of Chemistry at UCV quite often invited well-known professors from other countries to give seminars and lectures in order to acquaint students with these persons and their programmes. A first publicly funded training programme (1968–1973) was organised to send students abroad on scholarships. Although established in conjunction with the French embassy, attempts were made to prevent it becoming dependent on a single scientific 'culture'. Scholarship holders thus went not only to the French Petroleum Institute (IFP) (industrial research) and the Institute of Catalysis Research (IRC) in Lyon (basic research) in France, but also to the Ipatieff Catalytic Laboratory in the United States, the *Instituto Roca Solano* in Madrid in Spain, the University of Munich in Germany, Czechoslovakia, and so on.

At the end of the 1960s a small catalysis group had been established at the UCV when calls for university reform resulted in disturbances that led to the temporary closure of the university. A French delegation that had been invited by the government to come to Venezuela at this time visited several university institutions and inspired various students to take up postgraduate work in France. At the same time, as the result of an independent initiative, an agreement was signed to establish a university institute of technology in the metropolitan region (IUT-RC) on the model of the French university institutes, which would receive considerable assistance from the French government for the purchase of equipment and training[4]. As part of the exchange programme a number of young French *coopérants*[5] went to Venezuela, continuing the experiment that had begun a few years before in the UCV faculty of science. From the beginning IUT/RC included catalysis among the subjects covered by the educational training plan, with a view to producing high-level experts for the oil industry in view of the imminent nationalisation of the oil and petrochemical industry.

In February 1977 there was another visit to UCV by French experts on catalysis. During that visit several preliminary joint research projects were drawn up. On the occasion of the Fifth Ibero-American Catalysis Symposium in Lisbon in 1977, the group of Venezuelan participants (from UCV, the University of Carabobo (UC) and the Venezuelan Institute for Scientific Research (IVIC)) had an informal meeting with Raymond Maurel, at that time Director of the Catalysis Laboratory at the University of Poitiers, with a view to possible scientific technological cooperation in the field of catalysis and the chemistry of hydrocarbons. As a result, high-level French researchers and representatives of the French petrochemical industry visited Venezuela to take part in a working meeting coordinated by CONICIT, which was attended, in addition to the university groups, by members of INTEVEP and representatives of the private industrial sector in Venezuela. In 1978 Venezuelan researchers were invited to France to visit laboratories carrying out research in catalysis. This visit gave rise to joint research programmes, which seem to have been a reformulation of the proposals discussed at the 1977 meeting. Plans also emerged for exchange visits to discuss and evaluate the progress of research.

In 1983 the First Franco-Venezuelan Symposium on Catalysis was held in Caracas on the initiative of professors and lecturers at UCV and with the support of the scientific and technical services of the French embassy in that city. A report by the French embassy noted that there were "numerous francophones and francophiles" among Venezuelan teachers and researchers in catalysis. While recognising that in general the influence of the US and the UK was predominant, it was pointed out that over half of Venezuelan researchers in catalysis had been trained in France. The importance of the relationship with France for the Venezuelans was underlined by the inclusion of a Franco–Venezuelan meeting among the events organised to mark the twenty-fifth anniversary of the founding of the faculty of science at UCV. The numerous discussions helped reinforce existing bilateral programmes and to establish new contacts. New projects were launched, particularly on homogeneous catalysis, a field in which relations had been established more recently.

The French proposed a return meeting to be held two years later in 1985 in France, attended by the same group of academics and

industrialists specialising in heterogeneous and homogeneous catalysis. In 1985 there was an assessment of postgraduate work at the UCV School of Chemistry, which offered a Master's degree and a doctorate with options including the development of heterogeneous catalysis. M. Goldwasser and F. Parra came up with the proposal that was to lead to the first Postgraduate Cooperation Programme (PCP) between CEFI-International, a body promoting agreements on cooperation with France, on engineering, and CONICIT. That same year 14 Venezuelans, chosen from 20 candidates, attended a symposium on catalysis at Rueil-Malmaison, with the collaboration of the French Government, ELF, TOTAL, Procatalyse and IFP, in addition to CONICIT. In 1986 a French report observed that relations between the two countries in the field of science were well established, and Guisnet visited UCV in his capacity as director of catalysis at Poitiers to establish a joint Master's degree between UCV and Poitiers University. A cooperation agreement was signed in due course and the first PCP was thus launched.

Structured programmes for cooperation in catalysis

During the 1970s, when collaboration with Venezuela in the field of catalysis first began, the most important figures in the field in France were involved in its organisation. R. Maurel was the most powerful figure in chemistry in France as Director of the Department of Chemistry at CNRS, where he had already initiated international programmes. His connection with catalysis in Poitiers had begun sometime previously when he was director of the catalysis laboratory at that university. In an interview he recalled that Poitiers University's collaboration with Venezuela had begun around 1969–1970, on the initiative of the Venezuelan Federico Rivero Palacio, the founder of the first university institute of technology in Venezuela. It was the catalysis laboratory directed by Maurel that produced the chemistry graduates who went on to Venezuela to work in the brand new IUT in Caracas. In this way Venezuelan researchers were very rapidly brought into contact with French laboratories and took advantage of the opportunities provided by the special position of catalysis in chemistry in France.

The PCP is a programme focusing on the training of researchers. However, it is much more than a fellowship programme. It organises ongoing exchanges of research workers on the basis of shared interest in a more intense and structured form than training programmes in other European countries. The process of collaboration was organised on the basis of specific agreements to improve planning and give a strategic view of the two countries' joint research activities. In the case of petroleum, the support of INTEVEP and IFP, the public R&D centres for the oil industry in the two countries, was sought. The French model appeared relevant because the French oil companies, Elf and Total, were also public companies, and had served as models for some less developed countries when they decided to promote development through state action.[6] For the French the advantages of the PCP lay in their own experience in international cooperation, in obtaining more students with access to the laboratories of a country that had an oil industry and the possibility of increasing the number of joint publications. The Venezuelans were seeking to build bridges so as to send their students abroad and escape isolation, not to mention the prestige of international collaboration that would increase their credibility and set the seal of approval on their work. The distinctiveness of the PCP as a form of collaboration lay in the stress laid by its promoter, Mr Guibert, on the need to establish international collaborative projects that were of direct concern to industry. He saw it as a means of promoting French engineering and a particular view of French industry. Against that background, it is perhaps paradoxical to point out that the PCP catalysis research programme was restricted to research which, although of interest to industry, does not involve the technologies that the oil industries can directly market or use.

The first PCP agreement between CONICIT and CEFI provided for postgraduate study (Chemistry, Physical-Chemistry option) in the School of Chemistry of the UCV faculty of science (coordinated by Mr S. Goldwasser) and study for a *Diplôme d'Etudes Approfondies* (a Master's degree)[7] in applied chemistry at Poitiers University (coordinated by Mr Guisnet). The

Genetics laboratory in France. J. Grison/Rapho

purpose of the agreement was to enable students who had obtained their first year degree at UCV to enrol for the Poitiers Master's degree by correspondence, while at the same time a maximum of 10 Venezuelan postgraduate students were given the opportunity to attend courses abroad, helping to establish links between the main groups involved in heterogeneous catalysis in Venezuela (School of Chemistry and Faculty of Chemical Engineering at UCV, IUT-RC) and various French teams (LACCO-Poitiers, LURE-Orsay, URA 402-Lille and IRC-Lyon), at minimum cost for the country of origin and great benefit for the training of students. The main focus of the research programme was the development of zeolites and similar materials.

At the meeting at Rueil-Malmaison in April 1985, it was proposed that a joint research programme (PICS)[8] should be established to study the treatment of heavy crudes and residues, homogeneous catalysis, and fine chemicals. The initial responsibility for preparing the proposal was entrusted to Orlando Leal, representing the Venezuelan Catalysis Association, and Pierre Gravelle, President of the Catalysis Division of the French Chemical Society. Writing to Leal in January 1986, Gravelle suggested as a subject for collaboration the conversion of heavy crude oils, including the treatment of petroleum residues, arguing that French companies (Elf-France, CFR and IFP) were already collaborating with the CNRS in this field. He assumed that a similar agreement existed between INTEVEP and the Venezuelan universities. The French companies had concluded an agreement with INTEVEP and therefore placed no restrictions on the collaboration of French university chemists with Venezuelan laboratories in these areas. He asked Leal to consult INTEVEP and inform him of its opinion on this collaboration.

Gravelle also sent a message to the Director-General for cultural, scientific, and technical relations of the French Ministry of Foreign Affairs, which is responsible for supporting France's bilateral scientific relations, and to the Directorate of International Relations at the CNRS regarding the establishment of an International Programme for Scientific Cooperation between France and Venezuela on the conversion of heavy crudes and residues. He pointed out that the definition and development of improvements (responding to the severity of anti-pollution laws) were, in France, one of the main focuses of a research programme involving the two major French oil companies and the French Petroleum Institute (IFP), which had joined forces to work in this direction in the Association for the Enhancement of Heavy Crudes (ASVAHL). On the basis of an agreement between CNRS and the members of ASVAHL, research projects had been carried out since 1984 on thermal and catalytic processes for the enhancement of heavy crudes and refinery residues. Despite the slowdown resulting from low oil prices, the enhancement of heavy crudes continued to be a priority objective for Venezuela: the recoverable reserves of extra-heavy oil in the Orinoco Belt represented 44% of the world's reserves of that type of crude oil. For several years now, INTEVEP and university catalysis laboratories had been carrying out joint research on the conversion of heavy crudes and their demetallisation.

Thus, after 15 years of fruitful collaboration between the French and the Venezuelan teams and one year after the establishment of the first PCP in catalysis, the first PICS (International Programme for Scientific Cooperation) in catalysis was signed in 1988. This was the first international programme established under the auspices of CONICIT–CNRS, having as counterparts IPSOI (Institute of Petroleum and Industrial Organic Synthesis), IRC (Institute of Catalysis Research in Lyon) and the Chemical Coordination Laboratory in Toulouse on the French side and IVIC, UCV, and INTEVEP[9] on the Venezuelan side. The research efforts of this programme were directed towards the optimisation of methane in homogeneous phase or through the use of supported catalysts. A focus of both programmes during this first phase of bilateral cooperation was the study of the HDS process as there was a need at that time to improve knowledge in this area on account of the kind of crude oil that was being processed in both countries.

Following a series of discussions in 1990–1991 the work of the teams of the PICS and PCP were increasingly directed towards "organic synthesis by means of catalysis".[10] Although efforts were made to link the two programmes around the common theme, it was

clear that most of the work concerned either homogeneous catalysis or heterogeneous catalysis and not both kinds of catalysis at the same time. In fact studies for a French doctorate (necessary for the PCP) only covered one of these disciplines and was carried out in laboratories specialising either in heterogeneous catalysis or in homogeneous catalysis. In 1991, following a favourable assessment of the four years of the PICS, Basset thought it advisable to bring it to a close and gave various reasons for adopting a new subject area while maintaining the close links built up over more than 20 years:

1. The scientific priorities of the two countries had changed over this period. In particular, environmental chemistry and selective fine chemistry had become priorities in both countries;
2. It was necessary to explore new areas so as to avoid 'thematic sclerosis';
3. It had become clear that new people needed to be put in charge after the completion of a given programme;
4. The wish to combine the PICS and the PCP (which to some extent represented research and training respectively) would inevitably lead to the appointment of a single person with overall responsibility;
5. The wish of the CNRS not to systematically renew the PICS programmes on a specific subject so as to leave room for other disciplines and other subject areas.

In 1992 CONICIT's budget was increased fourfold and there were plans for massive investment in the country over the following 10 to 15 years, mainly in the petrochemical and natural gas sectors, with an estimated need for 5,000 chemists over the following five years.[11] The situation of the petroleum industry was particularly interesting: the direct marketing of heavy oils and residues was already a reality thanks to the Orimulsión® process (Vessuri & Canino 1996). However, independently of whether this approach made possible the initial enhancement of heavy crudes, their refining and deep conversion would become essential. The hydro-conversion of residues was the technique most conducive to their optimisation through transformation into fractions of gasoline and gasoil. Among the processes available in international petrol companies, INTEVEP'S HDH process was one of the easiest to use and one of the most original in terms of the design and use of the catalyst. That could hardly be said to be a coincidence, since it was a vital priority for the Venezuelan oil industry, but it had been achieved efficiently and rapidly, bearing in mind the recent emergence of petroleum research in Venezuela. Tests had been carried out in the form of a pilot project and the HDH process had been tested in a unit with a capacity of 20 T/d. The engineering design of a commercial unit was near completion.

INTEVEP'S applied catalysis section had reached a respectable size (a team of some 50 people) and was hoping to become a department, which, in INTEVEP's very hierarchical administrative structure, would give it a degree of additional freedom in choosing the particular scientific directions it wished to pursue. However, at that moment in time it became clear that Venezuelan industry was in deep financial crisis, and a national debate was initiated on whether or not to allow foreign capital to be invested in any future refineries. It was against this background that the plans to construct a demonstration unit for the HDH process were shelved, as was the construction of a plant for deep conversion of residues at the Jóse petrochemical complex.

These circumstances were also analysed on the French side and an attempt was made to devise a joint research programme that could be applied in the long-term, excluding industrial developments in the short and medium term, not only so as to avoid hurting local feelings, but also to prevent the coexistence in French laboratories of research projects that would involve competing petroleum groups. INTEVEP was one of the natural employers of Venezuelan graduates with a training in catalysis, since it concentrated most of its resources in applied research in this field. As such it sat on the examining boards that awarded PCP scholarships. The French wished to see INTEVEP much more effectively integrated as a partner, especially with regard to the subjects of dissertations, lines of research and, possibly, funding. It was precisely at that moment, breaking with the policy that it had pursued hitherto, that the Venezuelan oil industry decided to cut its links with the programme, declaring that it could use

its own resources to carry out its research and development programmes and train the human resources that it might need. Subsequently, this decision was reversed and INTEVEP has continued to work as a partner.

The successive mission reports, closely monitoring the progress of the two programmes, make it possible to identify the policy followed by the participating groups. An evaluation in March 1993 qualified positive aspects with the observation that the stability of the team as a whole pointed to a failure to recruit young researchers to regular posts. That implied two negative consequences: an ageing of the whole structure, with the risk that productivity would be reduced, and the impossibility of ensuring continuity of the potential for research. Those in charge of the programme were recommended to make better use of the procedures and facilities provided by CONICIT, such as the Innovative Research Programme (PIN), while at the same time it was pointed out that the new direction in environmental chemistry made it advisable to re-examine cooperation strategies so as to preserve achievements and ensure a closer match between programmes and structures (for example, CNRS/European Community). The size of the budget for the Catalysis PCP inevitably gave rise to an insistence on results, particularly as regards effective joint action with the PICS. The agreements being negotiated were evidence of this determination to achieve results.

In 1994, in an evaluation of the PICS-PCP network, which since 1992 had formally concentrated on fine chemicals, Gravelle contended that the experience of the network clearly showed the benefits of linking a PCP with a PICS of the CNRS as a means of ensuring greater visibility of the programme for the CNRS, and of obtaining incentive funds for the French teams, etc. However, he did not recommend merging the two collaborative structures, as had been done in 1992, since it was anticipated that the new PICS needed to include not only catalysis teams but also teams specialising in mineralogy and theoretical chemistry, which meant that specificity of the PCP (training in the field of catalysis) might be blurred. The report proposed, however, that the new PCP in catalysis should be carried out in close conjunction with the new PICS. INTEVEP and Total supported these measures in terms of both the funding and the cooperation involved. On the French side, Elf, BP Chemicals, and Hoechst sponsored the research. CONICIT's 'Petroleum Agenda' project also helped to reinforce the programme on the Venezuelan side.

At the most recent meetings of the programme, the Venezuelan researchers suggested that it might be helpful to extend the coordination and integration arrangements to include other Latin American groups with which France had similar bilateral agreements. The meeting on catalysis, jointly organised with France, held in Caracas in October 2000 pointed in that direction, anticipating a greater degree of coordination, with new participants and new themes and actions, both between the national research groups (there are already 10 Venezuelan institutions that have groups working on catalysis) and between the other countries of the South American region that operate exchanges for training and research with France (Argentina, Brazil, and Colombia), and possibly Chile and Uruguay.

Discussion

The collaboration between Venezuela and France in the field of catalysis is exceptional from several points of view. Several institutional formulas for cooperation, have been put to the test, initially on an informal basis, subsequently organising joint training, as under the PCP, or restricting activities to research, as under the PICP. The collaboration has extended over a long period and involved a considerable number of participants in this area of knowledge. Its effects are to be seen in the objectives and focuses in coordination, in the students' interests, and in the possible uses of the results, as well as in the influence of the collaboration in more general terms.

How are the objectives and focuses of the programme decided on?

As we have seen, the two sides involved in the collaboration first entered into contact many years ago and in both countries a central nucleus has to a large extent continued to

exercise control. This seems to be due to a combination of factors: the most advanced centre of training in Venezuela was the School of Chemistry at the UCV faculty of science and it continued to produce the largest number of graduates. On the French side, too, relations with Venezuela were mainly based on the graduate training programmes for the Master's and Doctor's degrees at Poitiers University and the research centres in Lyon. The working relationships and mutual trust built up by teachers and their ex-students expanded over a period of time. However, the restrictiveness of the central group imposed limitations, ruling out, for example, the extension of the programme to other research centres, in particular in France. The French participants that did not belong to the central nucleus complained on several occasions that their (French) colleagues did not allow more leeway for new openings. On the Venezuelan side, although the same complaint was also heard, there were fewer alternative groups and therefore the opportunities for extending the range of the programme seem to have been regarded as somewhat limited in the past, although the situation could have been altered without causing too much unpleasantness.

As might be expected of a programme lasting 14 years, there have been changes in the focuses of the collaboration. However, developments in this field at the international level lead us to believe that more radical changes will need to be made in the short term.

Themes of the PCP and PICS agreements in the field of catalysis

1987: First PCP on catalysis. Study of systems (processes) that used heterogeneous catalysts produced on the basis of modified zeolites.

1988: First Catalysis PICS on the optimisation of methane in homogeneous phase or with supported catalysts.

(A focus of both programmes during the first stage of bilateral cooperation was the study of the HDS process, owing to the need to extend knowledge in this area because of the kind of crude oils that were being processed in both countries).

1992: Cooperation agreement (PCP+PICS) to carry out work on fine chemicals (catalysis of processes relevant to the selective development of products that came within this class of world production).

1995: It was considered advisable to partially retrace the initial steps and a new direction for the two programmes was approved.

1996: PICS: Treatment of heavy and extra heavy crude oils.

1997: PCP: Catalytic processes related to petrochemistry and oil refining.

Interests of the student: The French researchers now recognise that previously they generally accepted foreign students without considering what the students themselves wanted to do. Relations have evolved, however, and now there is much greater responsiveness to the candidate's wishes. An initial informal contact is established with the candidate and his/her tutors in their country of origin, and the fact that the programme is structured around a broad but sufficiently specific set of themes means that it is possible to take full account of both the interests and benefit of both parties. Thus, much of the interest of programmes such as the PCP and the PICS lies in the fact that the training of the future generation of researchers in a given field is carried out within an organised framework. Table 2 summarises the total number of exchanges under the training programmes (PCP), with the qualification that the programme cannot cover all the specialists in catalysis that have been trained in France, since a number were trained during the period of contacts prior to the signing of the first agreement. We can state therefore that the joint research programme offered a very effective form of training, the consequences of which are still to be seen.

Application of the results

Several of the persons contacted pointed out that few of the studies carried out in the framework of the research network in catalysis in fine chemistry had received direct support from industry. The few exceptions were INTEVEP's contribution to funding scholarships to complete a thesis and the occasional study supported by IFP in France. This situation is due, on the French side, to the difficulty of obtaining industrial support in the field of fine chemicals, on

TABLE 2. Exchanges within the catalysis PCP

Year	Doctorate Students (t-months)	Post-doctorate Professors (t-months)	Research[a]	Total Persons (t)
1988	3 (7)	1 (6)	**	4 (13)
1989	1 (12)	4 (33)	**	5 (45)
1990	3 (13)	3 (9)	**	6 (22)
1991	7 (43)	**	**	7 (43)
1992	8 (42)	1 (7)	**	9 (53)
1993[b]	4 (24)	4 (8)	5 (2)	18 (52)
	1 (12)		4 (2)	
1994[b]	2 (15)	1 (0.5)	2 (1.5)	9 (25)
	1 (6)		3 (1.5)	
1995[b]	4 (18)	2 (13)	**	12 (45)
	1 (12)		5 (2)	
1996[b] (1st half)	3 (13)	1 (4)	1 (0.5)	6 (20.5)
	1 (3)			

[a]The first figure shows the number of Venezuelans going to France, while the second figure shows French students going to Venezuela. An asterisk indicates no movement.
[b]From 1988 to 1992 the expenses of Venezuelan researchers going to France and vice versa were funded by the researchers themselves through other kinds of programmes (e.g., CDCH-UCV, S1-CONICIT, etc.)
Source: CONICIT, Caracas.

account of the acute problem of industrial property, and, on the Venezuelan side, to the scant interest shown by Venezuelan industrialists in this kind of chemistry. Thus, contrary to the hopes expressed when the PCP was renewed in 1992 in the climate created by the signing of the first BID-CONICIT agreement on new technologies, fine chemistry has not developed in Venezuela, and is not likely to develop in the near future as the current producers control the markets in the finished products. The areas studied under the PCP, which are on the fringes of fine chemistry – hydrogenation of the aromatic cycles of nitrogenated molecules, activation of alkanes – and which, although far upstream, are close to some processes in petrochemistry, have benefited indirectly from the support provided by oil companies in these fields.

However, the industrial benefit of a programme in an area such as catalysis lies in something that is more difficult to measure: the capability that it confers for analysing and developing a very specific area of technical knowledge. Technological developments in the Brazilian oil industry such as offshore exploration (Furtado 1998) and the establishment of a catalysis plant in Rio de Janeiro (Antunes *et al.* 2000) demonstrate that a developing country can reach the cutting edge of technology thanks to a coordinated effort with foreign partners. Catalysis research provides the industry with information on the progress of scientific knowledge and the most recent scientific findings. The presence of doctoral students helps to maintain a level of expertise in the field and in this way a relatively cheap pool of skilled human resources has been created. It is up to industry to make effective use of it.

Shared coordination of the programme

The collaboration that we have described, in its various forms, has always relied on experienced scientific administrators. In both France and Venezuela their role to a large extent was to protect the programme from sudden changes of direction at a national political level, seeing it as their main objective to ensure the smooth and successful functioning of international cooperation. They sought to solve the specific problems that occurred within the framework of the programme itself, and avoided getting involved in national politics, where their power and control would have been limited. They appear to have enjoyed a considerable degree of autonomy, which is not surprising, since when a programme is seen as dealing with basic science the governments participating in the bilateral association usually leave it to the scientists to propose research projects that will help to develop expertise, strengthen the country's image as a leader in the scientific and political fields, increase its prestige and reinforce its alliances. It is only when the programme impinges on strategic areas of research that the coordinators find themselves restricted by national policies and lose their authority to take key decisions. In the case of catalysis this became obvious on those occasions when the interests of the national oil industries conflicted with the interests of those involved in the catalysis PCP.

Conclusion

The programme of collaboration described above lasted quite a long time and dealt with

areas that were of strategic importance not only from the economic point of view, but also from the geo-strategic point of view, given the importance of oil as a resource. In recent years the political will to develop cooperation has been reaffirmed. Decisions regarding the way in which this should be done are always the result of a complex combination of factors and are approached in various ways depending on the position of those involved.

The French authorities regard such cooperation as particularly useful material for analysis with a view to improving national policy on collaboration with developing countries and as providing an opportunity to examine such problems as the way collaboration would be organised, the relationship with commercial interests, and the best way of institutionalising valid evaluations of such programmes. We have carefully examined the relative autonomy of the scientists and the way they manage international programmes. They act on behalf of their country, respecting the scientific competence of their peers. In some cases a kind of 'teacher-disciple' relationship seems to have persisted, in other cases the interaction is with their 'counterparts' in the other country, depending on the institutional background on both sides. We believe that the various types of arrangements for cooperation now require in-depth evaluation.[12]

For the Venezuelan authorities this programme also provides a framework of reference, since various forms of linkage have clearly been established simultaneously with or as a consequence of PCP activities. Privileged relationships were established with the institutions at which the local researchers had studied in the partner country and, through contacts and exchanges within the PCP, Venezuelan researchers were helped and encouraged to participate in international research and development programmes such as the programmes of the European Union, in which other countries were active. This shows once again that the network to which researchers have obtained access is probably more important than actual research findings. Public and private companies can also turn to this network to make effective use of the pool of high-level expertise to which it gives access.

Finally, as far as researchers are concerned, there is a need to take into account the consequences of the internationalisation of scientific activity and therefore, of the internal life of organisations such as universities, public research centres, and R&D laboratories, and also the far-reaching changes in the very nature of scientific work that have occurred in recent decades and as a result, in what it means to be a scientist today. International collaboration is more than a means of obtaining access to the prestige conferred by international recognition. It seems to us that the validity of the work done by Venezuelan researchers and the fact that they were able to make use of the strategic resource represented by the PCP and PICS programmes, in conjunction with their French colleagues, show that such programmes are more effective when an activity at the national level can be *linked,* within national scientific and political institutions, with an activity of international scope. We have thus been able to confirm a conclusion reached by researchers using bibliometrical data concerning the need for linkage between what is done inside and outside a country (Eisemon & Davis 1989, Russell 1998). A programme of collaboration that consisted simply of sending Venezuelan researchers abroad would probably have been a failure and would not have had such an impact on foreign colleagues, or on politicians and industrialists. It is in helping to create a national scientific community that this venture has been so successful. It has been said that the emergence and strengthening of a scientific community in many respects enhances the ability of both the industrialised and the developing world to collaborate with each other (Gaillard, Krishna & Waast 1994). The programme that we have examined here provides an excellent example of this.

Notes

1. We have drawn on the extensive stock of evaluation reports on the programme that we were able to assemble from the French Embassy in Caracas and from the national coordinators of the programme and on those provided by Mr Roques, general coordinator of the PCPs in Pau. Information was also obtained from our visits to the main centres involved and from interviews with the participants in France and Venezuela.

2. Ceruti mentions the comment of one industrial researcher: "Procedures for catalyst manufacturing are usually developed in an *empirical way*, through time-consuming and costly work, though some attempts of a *scientific approach* begin to appear in the literature."

3. We do not wish to return here to the theoretical debate on the usefulness of science, which we have discussed on other occasions: Arvanitis 1996, Arvanitis & Dutrénit 1997, Vessuri 1990, 1995.

4. Some idea of the scale of French cooperation during these years may be indicated by the fact that between 1971 and 1981 IUT-RC alone sent to France 304 fellowship-holders out of a total of 430 distributed among other institutions in Venezuela itself, the US, the UK and Canada, that is to say, 71% of the total.

5. *Coopérants (Volontaires du Service national* or VSN) were young French university students who spent some time abroad as teachers or laboratory assistants under the auspices of the French scheme of *Coopération*, as part of their military service.

6. The history of Elf and of Elf Aquitaine, especially after the loss of Algeria, is very illuminating in this regard. Following that event France decided to become a major oil country. With the privatisation of Elf, the national model ceased to exist. Recently, the takeover of Elf by Total-Fina finally put an end to any lingering desire on the part of the French state to develop a national model for the oil industry.

7. The *Diplôme d'Etudes Approfondies* is a compulsory prerequisite in France for going on to study for a doctorate.

8. A PICS is a CNRS cooperation programme for research, involving collaboration on an equal basis in which the work of one party complements that of the other. It lasts three years and funding for each part is obtained from both countries. The joint programme covers the costs of the cooperation: travel, living expenses, communication, etc.

9. The latter withdrew, citing problems linked to what it called the total confidentiality necessary for findings of interest to this industry.

10. The two major research topics were linked to petroleum chemistry and strategic interests on both the Venezuelan and the French sides: (1) activation of the C-H link of methane and of the alkanes by heterogeneous and homogeneous catalysis, and (2) activation of the C-N link of nitrogenated hydrocarbons for the processing of heavy crudes.

11. Unfortunately, the funding of science in Venezuela did not maintain a constant rate of growth throughout the decade and stayed at around 0.3% to 0.5% of GDP from 1980 onwards.

12. Evaluation is particularly important in the case of catalysis involving France and Venezuela, in view of the fact that there are plans to replace the PCPs by cooperative programmes operating in a more traditional fashion (ECOS-NORD), thereby forfeiting the advantages of continuing evaluation and of the emphasis on the connection between scientific work and productive and economic interests.

13. Years for which Pascal CD-ROMS were produced. This information was obtained after keying in CATALY* for key words, titles, and abstracts on CD-ROMs. It cannot be regarded as exhaustive since PASCAL is a pluridisciplinary database. Its advantage is that it systematically records documents with an area coding for keywords. The database was slightly biased in favour of material in French up to the beginning of the 1990s, but was subsequently corrected so as to provide better coverage of the material in English. For this period the database recorded 431,422 scientific articles and 34,684 abstracts, papers for congresses, reviews and proceedings of meetings.

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