RESEARCH NOTES

*Institutions Linking Knowledge Generation with Knowledge Utilisation: The Case of Mexico**

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Background of Mexican Science and Technology

MEXICO ABRUPTLY BROKE the old protectionist economic scheme with its entrance to the General Agreement on Trade and Tariffs (GATT) in 1986, and became an open market economy, similar to the economies of highly industrialised countries. Later in 1994 Mexico signed the North America Free Trade Agreement (NAFTA) with the USA and Canada that relaxed even more the tax restrictions for import of products manufactured in the partner countries. In a few years national industry had to cope with the fierce competition represented by the import of high-technology value-added products.

The new rules of the global economy demand the modernisation of the industrial plant, imposing a new agreement among the factors of production, including science and technology as a very important component of the production system. The developed countries show a strong

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higher education institutions (HEIs)–industry relationship. In recent years as a consequence of the globalisation of the economy, this link has been enhanced, dedicating additional funds for technological renovation. The R&D budget in those countries, estimated between 2 and 3 per cent of GDP, is not comparable with the small 0.4 per cent that Mexico spends for the same purpose. The number of active scientists in Mexico is 5.5 per 10,000 workers: approximately nine times less than France or Germany, and sixteen times less than the United States or Japan. Moreover, opposite to what takes place in those countries, Mexican scientists and technologists are concentrated in public universities and research centres rather than in industry (Esteva et at. 1994: 9).

It is clearly inequitable to compare Mexico with its northern partners (the USA and Canada) or other first-world countries due to the great development difference. It would be fair to compare Mexico with other Latin American countries that show some relevance in R&D. When doing so, the data shows that the Mexican S&T expense with respect to GDP is less than in Cuba, Brazil, Chile and Argentina.[1] However, Mexico does better than Cuba and Chile, and is very close to Argentina with respect to the contribution of scientific articles published in the most prestigious journals of the world, while Brazil doubles Mexican scientific productivity.[2] The contribution of these five Latin American countries amounts to only 1.5 per cent of the world output.

Mexican public HEIs are the most important knowledge generator institutions in the country, and therefore must assume a more aggressive role vis-à-vis the urgent need to link relevant R&D output with the problematique of global competence of products and services.[3] To act correspondingly, they should seek, directly or indirectly, strategic alliances with the production sector, since HEIs currently face the challenge of being socially accountable within a context of scarce economic resources.

Some HEIs have direct linkages with industry with positive results. However, in many areas of research this linkage needs an 'intermediary' who plays the role of 'translating' the results of basic research and frontier technology to plausible applications in industry and the services. These 'intermediate' institutions are mostly missing in Mexico, with just a few gradually taking on that role. The different levels of government should play a central role in this task, not only as facilitators but promoting and partially budgeting this process, as is the case in countries like Japan (Goto 1995; Goto and Wakasugi 1987; Kahaner 1994). What follows is a brief account of the Mexican SEP–CONACYT Technology Subsystem, which is taking the role of a 'linking device' to fulfill the task of converting knowledge produced in HEIs into value-added applications.

SEP–CONACYT Centres: The Technology Subsystem

The SEP–CONACYT centres are R&D institutions subsidised by the Mexican federal government through the Ministry of Education (SEP) and the National Council of Science and Technology (CONACYT) (see CONACYT 1997, 1999a, 1999b, 2000a, 2000b).[4] In recent years these centres, as well as the rest of institutions dedicated to R&D, have been subjected to demands in terms of the so-called 'social accountability' understood as the obligation to return to society, in the form of 'tangible products', part of what they get for the benefit of all. Recently an effort has been made to convert this set of separate centres into a 'system' in the sense of making them interact to achieve mutually agreed objectives. The SEP–CONACYT system currently includes a total of twenty-eight institutions, which may be grouped into three subsystems: ten in the Scientific Research Subsystem, another ten in the Social Sciences Subsystem, and seven belonging to the so-called Technology Subsystem. An additional centre, INFOTEC, offers services on information and organisational technologies.

Most of these centres were created during the 1970s. Considering only the Technology Subsystem, five out of its seven centres were founded between 1974 (Centre for Research and Applied Chemistry [CIQA]) and 1978 (Centre for Research and Technical Assistance [CIATEQ]). Unfortunately, that pace could not be maintained, and in the following two decades only two new centres were created: one in 1984 (Centre of Industrial and Development Engineering [CIDESI]) and the second one in 1991 (Centre for Electrochemical Research and Technology Development [CIDETEQ]). The creation of technology centres was the product of individual or group efforts, not responding to government policy as it occurs in other countries. They started to operate in a rather isolated fashion, not only in the geographic sense, but also in terms of their relevance as an important component of a national system of innovation, still absent at that time.

The Technology Subsystem: Regional Coverage and Disciplinary Expertise

The Centre for Research and Technology Consulting for the Leather and Shoe Industry (CIATEC) was created in 1975, and gears its operation towards manufacturing processes for the leather and shoe industry as well as other related areas. It also focuses on product design and development, as well as in the design and optimisation of industrial processes, metrology and training. It is conveniently located in the city of León, state of Guanajuato, matching the location of the industrial sector it intends to serve.

Strategically located in Mexico's second largest city, Guadalajara, the Jalisco State Centre for Research and Consulting in Technology and Design (CIATEJ) was founded in 1976 to serve the jewellery industry. However, after major changes in its objectives and operation, this R&D institution is now centred around food and fermentation processes in agro-industry for the production of food, beverages and additives. Lately, it has entered a vast research area linked to the treatment and disposal of food-related effluents, massive food production, genetic improvement and the tequila industry.

The Centre for Research on Applied Chemistry (CIQA) is the eldest institution in the subsystem, created in 1974, and it is primarily devoted to research on polymers. It is located in Saltillo, one hour away from Monterrey, north-east of Mexico City, the third most important city in Mexico.

The Mexican Corporation on Materials Research (COMIMSA) was created in 1975. It is currently the sole institution possessing a different legal figure. It is the only one from the whole SEP–CONACYT system that was conceived as an enterprise. Its activities are oriented towards various metallurgy-related areas. It is located in the city of Saltillo, the same as CIQA.

Another important Mexican state in terms of its industrial development and potential is Querétaro, a three-hour drive from Mexico City, where three more centres are suitably located. The Centre for Research and Technical Assistance (CIATEQ, 1978), the Centre of Industrial and Development Engineering (CIDESI, 1984) and the Centre for Electrochemical Research and Technology Development (CIDETEQ, 1991) share some common interests. CIDESI and CIATEQ are dedicated to mechanical and systems engineering, thus having the opportunity of multiplying their capacities and strengths through mutual collaboration. CIDETEQ has selected as its main concern electrochemical processes.

Institutional Dimensions

The number of employees in the Technology Subsystem is large compared to the rest of the SEP–CONACYT system. By 1998 there were 1,757 workers, thus making the average size almost 251 per centre. However, the range is wide, going from sixty employees in CIDETEQ to 850 in COMIMSA. The Scientific and Technological Personnel (S&TP) are defined as those workers with higher academic degrees, and/or having plenty of experience in their areas of expertise, generally composed of well-trained engineers. Data for 1998 show a total of 1,472 S&TP persons.

This group of R&D centres does not include the high percentages of researchers with graduate degrees as opposed to most academic institutions. However, it is not necessarily scientists but engineers who have proven to be more adequate to the type of projects being carried out, and those which are sought after in the attainment of institutional objectives. They are part of the so-called 'technological personnel' and it is widely accepted that their areas of expertise and training are not associated with the attainment of a graduate degree. Indeed, the nature of problems this type of personnel face in industry generally does not require highly sophisticated scientific knowledge, since in most cases they are not in the frontier of high-tech. Since the technology centres are primarily dedicated to satisfy the industrial technological needs at high-quality standards, it is only natural their academic personnel have a low participation in the National System of Researchers (SNI, for its name in Spanish), where publishing scientific papers in renowned international journals is the major parameter to be considered.[5]

Graduate degrees are required in order to become a member of the SNI. It is generally accepted that a higher academic degree is necessary for developing ambitious and innovative S&T projects. Unsurprisingly, CIQA and CIATEJ are the only two centres where more than half the researchers are SNI members. Indeed, they are the ones with the larger number of researchers with graduate degrees. Unfortunately, the composition of some centres' does not allow for involvement in projects demanding more advanced technology and knowledge since more than half their S&TP do not possess university degrees at all.

Academia–Industry Relations[6]

Not all centres belonging to this subsystem have been instrumental for the modernisation of industry. Unfortunately, some centres have played minor roles in the insertion of industries to mainstream economy. In terms of their teaching activities, there is room for improvement in all of them, not only in their participation in the graduate programmes being offered by HEIs, but also in the realisation of special training programmes for industrial personnel. A final component to be assessed is the performance of high-level scientific research and technology development, in which at most three centres qualify: CIQA, CIDETEQ and CIATEJ.

Institutional Liaisons and Industry Interactions

All links established by these centres, including those within the SEP–CONACYT system, have to be understood in a wider context of articulation with other entities (CONACYT 1998). An indicator used to measure their level of activity is expressed in terms of the economic resources they generate. A more refined indicator is the ratio of *contract income* to total budget.[7] On the one hand these simple indicators allow the assessment of how tight and profitable the links established by the SEP–CONACYT Technology Subsystem with industry are. On the other they also show the likelihood of an economic self-sufficiency, an issue that has lately become worrisome, especially for those whose budget is still highly dependent on federal subsidies. Economic self-sufficiency offers a challenge in itself. Indeed, these centres ought to seek for projects where they may offer competitive advantages as well as more aggressive marketing strategies to reach out for new clients in the industrial sector, where they will be more likely to obtain a higher economic profit. A quick look at Table 1 gives us a clear image of the economic profitability of the centres. It could have been inferred that the longer a centre has been operating, the better its standing and competitiveness. However, the figures show that there is no direct relationship between age and profitability.

For instance, CIQA has been operating for 25 years in the same very well-defined field of research, and its self-generated resources are the lowest of the Subsystem (11.61 per cent). Likewise, centres like CIATEJ and CIDESI still lie below the 18 per cent barrier, and CIDETEQ, the youngest institution in the subsystem, whose size is half the others, is already making profits in the region of 14 per cent. The total budget for

TABLE 1
Distribution of Annual Budgets, 1998 (%)

Centre	*Own resources*	*Federal resources*
CIQA (1974)	11.61	88.39
CIATEC (1975)	21.05	78.95
COMIMSA (1975)	99.35	0.65
CIATEJ (1976)	17.61	82.39
CIATEQ (1978)	39.04	60.96
CIDESI (1984)	14.14	85.86
CIDETEQ (1991)	14.17	85.83

Source: CONACYT (1999b).

1998 shows an average of 31 per cent generated by the subsystem itself through contract projects and services, including COMIMSA, the single centre contributing the largest amount of self-generated income. As we pointed out earlier, COMIMSA was created as an enterprise. Thus, it was conceived differently than most R&D centres. In doing so, it has had the leadership needed to design and adopt successful business strategies. An example of the latter can be the development of links in the form of joint ventures with other centres within the SEP–CONACYT System to engage in R&D projects under COMIMSA's leadership.

Quite a different view results when comparing self-generated income and the total number of services. The latter by itself could lead to some misunderstanding of the concept of services rendered since it is not proportional to income. Table 2 gives an idea of which services are proving to be more profitable, in terms of the money they bring to the corresponding centre. Thus, CIATEQ is evidently a unit in good business, even though its number of services is the smallest in the subsystem.

TABLE 2
Profitability of Services, 1998

Centre	*Total services*	*Average income per service**
CIQA	546	9.89
CIATEC	6,864	1.08
COMIMSA	42,900	14.43
CIATEJ	2,709	3.07
CIATEQ	98	310.66
CIDESI	7,449	1.01
CIDETEQ	671	5.96

Note: * In 1,000 Mexican pesos (approx. 9 Mexican pesos per US dollar).
Source: CONACYT (1999b).

Another indicator that may lead to the design of service innovative alternatives deals with the ratio of total income generated per client or contract. From Table 3 it is clear that in 1998 CIATEC was the single centre to invoice 33 per cent from the total number of clients in the whole subsystem. However, the income generated by its clients accounted for only 1.1 per cent of the total figure of self-generated resources.

TABLE 3
Income Generated by Services Provided, 1998

Centre	*Clients (%)*	*Self-generated income (%)*
CIQA	7	0.8
CIATEC	33	1.1
COMIMSA	9	90.7
CIATEJ	14	1.2
CIATEQ	4	4.5
CIDESI	29	1.1
CIDETEQ	4	0.6

Source: CONACYT (1999b).

COMIMSA displays the opposite situation: it is the single centre absorbing 9 per cent of the total number of clients while obtaining from them resources enough to cover 95 per cent of their own budget, equivalent to 90.7 per cent of all the subsystem's self-generated income. While this performance may seem highly desirable for any institution, it certainly raises the question of economic dependability on very few clients.

Table 4 shows the centres' marketing ability in terms of projects being commercialised, in comparison with the total number of project developed during 1998. Even though it is clear that globally most of these projects were sold to industry, CIQA shows a much lower percentage (29 per cent), not reaching even the 50 per cent plus of the next lower centres, CIATEJ and CIDETEQ.

Indeed, it is clear that most centres in the Technology Subsystem are well capable of marketing their own products. However, they should assess the convenience of adopting new strategies, either to set up tighter links with universities and/or other R&D institutions or to get closer to industries and the private sector. The former would allow centres develop projects involving more sophisticated technologies; the latter would improve their marketing strategies even though it involves the risk of driving them away from its initial R&D mission.

The risk of becoming consulting- or service-oriented centres is latent. Available information shows that provision of services was their main

TABLE 4
Projects Contracted, 1998

Centre	*Projects developed*	*Projects commercialised*	*Proportion of commercialised projects to total projects (%)*
CIQA	17	5	29
CIATEC	515	515	100
COMIMSA	480	480	100
CIATEJ	83	44	53
CIATEQ	298	298	100
CIDESI	55	54	98
CIDETEQ	20	11	55

Source: CONACYT (1999b).

concern during 1998. Most of them devoted their S&TP time to short-term services rather than to project development (Zubieta and Jiménez 2000). Thus, any strategy geared towards the achievement of a self-financing status would inevitably lead to new but not necessarily most desired R&D objectives. Mexico has to recognise the need to develop appropriate technology to assure a future of economic independence. If R&D centres deviate their attention from S&T projects to technology services, the country will never be able to reach higher degrees of global competitiveness. Even though only a couple of these centres have been involved with teaching at graduate levels and only three of them do basic research, they all share as their primary objective the involvement in local and national industry problems, and the search for technology solutions.

Furthermore, since federal policies began to stress social accountability, especially during the mid-1990s, they have been urged to seek economic self-sufficiency, that is, to increase the share of their own resources with regard to their overall total expenditures. In order to do so in a more effective and efficient way, they realised they should enhance their level of activity in research, teaching and consulting appropriate to the local and/or regional demands already detected. Since they do not have the human capital required to excel in them, they have already started making decisions regarding the establishment of strategic alliances with universities and other R&D centres, in and outside the SEP-CONACYT system, which thus far has proved successful. Additionally, a set of policies are being implemented to this end:

1. an effective coordination among different participating actors (industries, firms, innovation centres, technology development institutions and universities);
2. the creation of information networks to facilitate and increase interactions among all actors involved, while promoting the use of knowledge springing from that relationship; and
3. the training of human resources in areas such as technical specialisation and scientific research.

It is widely accepted that much of the research done in higher education institutions is liable to add value to products in the market. However, the 'connecting device' (that is, the technology centres) have to develop and enhance their ability to understand the needs of the industry, and identify in academia the knowledge and the individuals who possess it, while helping in the 'translation' from academic to applied knowledge.

How this Linking is Done in Mexico

Mexican SEP–CONACYT technology centres have followed two different patterns of articulation to fulfil their purpose of being accountable to both industry and society: Model A and Model B. Model A emphasises the origin of some centres (especially CIQA and CIDETEQ) as closely related to research universities. On the other hand the origin of Model B centres (the remaining five centres) is connected with the satisfaction of industrial technology needs (Zubieta and Jiménez 2000).

Model A centres—CIQA and CIDETEQ—have the appropriate relations with HEIs that would support the realisation of applied projects at the frontier of knowledge. However, they do not have the proper penetration within the industrial world for the realisation of sound technology projects. Therefore, they have to make a special effort to cultivate professional relations with industry and 'sell' their potential research capabilities with the support of top university scientists.

In contrast, model B centres—CIATEC, COMIMSA, CIATEJ, CIATEQ, CIDESI—enjoy the confidence of the industrial sector. However, due to their limitations in top R&D knowledge, they are unable to offer support in applied projects with a substantial component of frontier scientific research. Therefore, Model B centres have to associate with personnel from HEIs that could fulfil the needs of top-level research.

Conclusions

It is well known that much of the scientific discoveries made in academia are not directly applicable in industry to add value to manufactured products. It is necessary to count with some interphase device that 'translates' knowledge into technological improvements of known products or into new products. The SEP–CONACYT technology centres are starting to fulfil this role in Mexico. National development Plans are formulated by law with a six-year periodicity at the beginning of each presidential mandate. The elaboration of the National Research and Development Plan, a segment of the overall plan, is coordinated by CONACYT, which seeks the participation of the scientific and technological community as well as the industrial sector to reflect the felt needs of those directly involved.

Although the plans are well-intentioned and reflect the needs of the country, in practice they are rarely observed. Moreover, the R&D plans do not set up specific goals and objectives to be met in determined periods of time. Nor are specific budgets allocated to areas of research that have to be enhanced. Rather, progress is made by the individual or group initiative of achieving some goal in a process of convincing the decision makers to allocate funds to particular projects. Mexico must learn from other countries' experience that if progress in terms of S&T development is to be realised, legislation and funding have to be hand-in-hand to put into effect concrete plans.

Data on the Mexican technology centres show that the potential to become an important factor in the economic competition in which enterprises are involved does exist. To properly fulfil there tasks, Mexican centres have to be involved in frontier technological research. To that purpose, some centres will have to make alliances with scientists of top HEIs to solve challenges that involve sound scientific knowledge. Others with scientific potential will have to seek relevant problems in manufacturing and industry in general, and convince industrial decision makers that they have the capability to solve sophisticated technological problems.

NOTES

1. UNESCO (1999) data shows that the 1995 R&D budget measured as percentage of the GDP for the countries mentioned above is as follows: Cuba 0.9 (1992); Brazil 0.84; Chile 0.67; Argentina 0.38; and Mexico 0.33

2. Data from the *Science Citation Index* shows that the per cent contribution in 3,300 journals of the 1994 index is as follows: Brazil 0.646; Argentina 0.352; Mexico 0.332; Chile 0.176; and Cuba 0.029 (Gibbs 1995). According to this criterion, the R&D Latin American 'giant' Brazil contributes with only a bit more than 0.5 per cent of the world total.
3. The term 'higher education institutions' encompasses all public universities and institutes with a budget for R&D activities.
4. For a detailed discussion on these R&D centres refer to Zubieta and Jiménez (2000: 37).
5. Created in 1984, SNI operates as a government agency closely related to CONACYT, and is in charge of fostering national S&T through incentives to individuals with a high academic performance.
6. All statistical informational provided in this section was taken from self-evaluation reports of the SEP–CONACYT system centres (CONACYT 1999b) presented to CONACYT and to their respective boards of governance during their second 1999 meeting, held in the month of May. Percentage figures and any other data manipulation are the authors' responsibility.
7. 'Contract income' is also referred to as 'self-generated resources', as opposed to the budget provided by the federal government, since these centres are all state owned, i.e., highly subsidised.

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