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KNOWLEDGE BASED DEVELOPMENT IN MEXICO: IS THERE A ROLE FOR THE UNIVERSITY?

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Resumen

Ahora más que nunca, se espera que las universidades contribuyan al avance económico de un país produciendo conocimiento tecnológico. Actualmente, la idea de que existe una relación causal desde la investigación que se realiza en las universidades a la innovación comercial y el desarrollo regional, es generalmente aceptada. El propósito de este artículo es examinar los esfuerzos que se han realizado para estimular la colaboración universidad-industria en el contexto de la economía mexicana, criticar sus resultados, y en el contexto de países desarrollados y en vías de desarrollo, analizar diferentes alternativas. La finalidad es estimular el debate y reconsiderar la generalmente aceptada, aunque poco explorada, conceptualización de la universidad como un "motor" del desarrollo económico.

Palabras clave: Universidad, vinculación, empresa, políticas públicas.

Abstract

It is generally assumed that there is a linear pathway from university investigation to commercial innovation to regional development and widening networks of innovation. The purpose of this paper is to examine efforts that have been made to stimulate university-industry collaboration in the context of the mexican economy, to critique their results, and, in the context of experiences in both developed and developing countries, to review alternative perspectives. It is hoped that this framework will stimulate researchers and policy makers to reconsider their vigorous but largely unexamined drive to conceptualize the university as the "engine" of economic development and to consider a more nuance role for the university in this process.

Key words: Pathway investigation, university, technological innovation.

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Technological knowledge and innovation are more and more conceptualized as the machinery that drives economic development. As evidence of the economic and social benefits that stem from exploitation of new scientific and technological knowledge accrues, the future well-being of industrialized societies is increasingly seen as dependent upon knowledge and innovation (Neef, Sesfeld, & Cefola, 1998; Nelson, 1996; Organization for Economic Cooperation and Development (OECD), 1997a, 1999; World Bank, 1999). The emphasis on the role of knowledge in global competitiveness for advanced economies has had a tremendous impact on the way that governments, researchers, and international development institutions have conceived the development process in developing economies. The World Bank, for example, has proposed to view the problems of development from "a knowledge perspective", according to which gaps in knowledge differentiate between developed and developing economies. This perspective emphasizes two interrelated mechanisms for economic development, both of which involve "catching up" by closing knowledge gaps. The first mechanism consists of the opening of channels for externally generated knowledge to flow to local industries in developing countries, thus enabling them to "catch up" through the informed selection, absorption, and adaptation of imported technology. The second relates to the eventual generation of indigenous knowledge through the strengthening of domestic research and development (R&D) capabilities (World Bank, 1999).

In this context, public interest in the university as the primary source of new skills, knowledge and ideas has placed it in the role of something akin to the fuel that drives the "engine" of development (Kodama & Branscomb, 1999). One result has been an intense drive by policy makers to actively encourage collaborative research relationships between universities and industry in developing nations, including Mexico. The impetus behind this drive rests on two related assumptions. First, it is assumed that there is a linear pathway from university investigation to commercial innovation, to regional development and widening networks of innovation (e.g., Florida & Cohen, 1999). Secondly, it is assumed that if institutional structures and relationships in developing nations, such as Mexico, can be transformed to replicate those observed in advanced industrialized nations, innovation and expanding innovatory networks will necessarily follow.

Pathways of development, however, are not necessarily linear, and the complexities of university-industry relations have not been fully understood, even in industrialized countries. Furthermore, a key difference between advanced industrialized nations and economic systems in the developing world is that the latter depend heavily on the ability to absorb and disseminate knowledge generated abroad. An important question in this context involves the degree to which university-industry linkages in developing economies like that of Mexico can realistically be expected to enhance the competitive performance of domestic industry. The answer to this question requires a deeper level of theoretical understanding of these processes than we have now. Perhaps the most problematic aspect of this drive to stimulate university-industry collaboration in developing economies, however, has been the failure to consider developmental pathways through which these relationships typically develop and the manner in which country- or culture-specific infrastructures enhance or limit these mechanisms.

The central argument of this paper is that a critical examination of the potential role of university-industry research linkages must include consideration of development as a dynamic rather than a static entity and must give thought to how specific cultural and institutional factors influence the industrial development process. The purpose is to examine efforts that have been made to stimulate these relationships, to critique their results, and, in the context of experiences in both developed and developing countries, to review alternative perspectives. It is hoped that

this framework will stimulate researchers and policy makers to reconsider their vigorous but largely unexamined drive to conceptualize the university as the "engine" of economic development and to consider a more nuanced role for the university in this process.

The role of the university in a knowledge-based economy

The crucial role of knowledge in modern society has been championed by a spectrum of academic, business, and policy sources. Terms such as the *knowledge-based economy*, the *learning economy* and more generally the *knowledge-based society* are commonly used in disciplines such as economics, history, and sociology, to describe advanced economies in which the production of goods and services is becoming increasingly knowledge-intensive via the better use of existing stocks of scientific knowledge, the diffusion of advanced equipment, and the managing of an increasingly complex knowledge base related to productive activities (Archibugi & Lundvall, 2001; Geuna, 1999; Lundvall, 1992; OECD, 1996, 1997; Rubenson & Schuetze, 2000).

Research in more advanced economies, particularly in member countries of the Organization for Economic Cooperation and Development (OECD), has provided evidence supporting the idea that R&D activities drive the economic success and competitiveness of innovative firms on both national and international levels (OECD, 1999). In the last decade, as these economies have moved from science policy with broad social objectives towards an innovation policy more narrowly focused on impacting economic performance, the connection between innovation and economic policies aimed at encouraging growth have become stronger and more direct (Lundvall, 2001; OECD, 1997a, 1999).

Now more than ever, universities are expected to contribute to the development of individuals who are prepared to acquire, transform and generate new technologies. Nelson (1993), for example, argues that "… universities play an extremely important role in technical advance, not only as places where industrial scientists and engineers are trained, but as the sources of research finding and techniques of considerable relevance to technical advance in industry" (p. 11).

Furthermore, in addition to the traditional role of universities in disseminating knowledge through publications for later application in industry, universities are increasingly expected to contribute *directly* to the creation of new products and services (Ludvall 2002).

The role of the university in Mexico

New patterns of university-industry collaboration have led to revised expectations for higher educational systems in developing countries. Traditionally, the role of Mexican universities in industry has been focused almost exclusively on the development of manpower. In Mexico, the generally poor innovation performance by Mexican industry has been perceived as a constraint on global competitiveness (CONACyT 1995, 2001; OECD, 1997b; World Bank, 1994). As a result, national policy makers and international development organizations have sought to bring about a more direct collaboration between Mexican universities and Mexican industry in order to foment the development of technological capabilities (Casas, 1997; CONACyT, 1995, 2002; OECD, 1997b). Modeled on university-industry relationships in knowledge-based economies, such as the United States and the United Kingdom, the expectation seems to be that if Mexican universities, motivated by higher education reforms and the demands of economic globalization, produce knowledge relevant for industry, they will naturally move to play a more central role in industrial development, similar to the experience of advanced economies. According to the World Bank (2000):

The largest role for universities is in carrying

out the initial research, but subsequent product development and distribution often result in a fruitful interplay between universities in industry. In many developed countries an increasing number of companies are spinning off from universities, a process that happens when researchers are encouraged to look for commercial applications of their work (pp. 80-81).

Morote and Yeager (2000) have argued that the future of the university in Mexico depends on the ability of universities to incorporate themselves into the development strategy of the country: "Universities, if they are to survive and prosper, will have to continue their efforts to develop linkages with business and industry. It will be through such changes that universities can become an important element in Mexico's sustainable economic development" (p. 220).

Results from efforts to stimulate university-industry collaboration in the development process in Mexico, however, have been generally disappointing. Formal collaboration aimed at the improvement or development of new products or processes has been scant, and highly trained manpower that is potentially capable of conducting research and development activities remains heavily concentrated in governmental and academic jobs (Casas, 2001; Casas, de Gortari, & Luna, 2000; Casas & Luna 1997; Economic Commission for Latin America and the Caribbean (ECLAC), 2001).

The few existing studies that have examined these problems have attempted to identify internal *causes* for the low intensity of industry-university relationships, focusing on local phenomena, including the bureaucratic nature of Mexican universities, their scant devotion of resources to research and development activities, and the lack of coordination policy initiatives that seek to stimulate collaboration (Castaños-Lomnitz, Didriksson & Newson, 1998; National Science Foundation (NSF), 2000; Valenti, Varela & Castillo, 2000; World Bank 2000). These analyses have generally failed to consider potential differences in pathways to development, ignoring, for instance, the response of Mexican firms to trade liberalization, market deregulation, and privatization of economic activities. As a result of these processes, Mexican firms are increasingly relying on external agents as sources of technical progress. Consequently, the demand from the Mexican productive sector for local engineering, highly-skilled manpower, and technological capabilities is shrinking (Katz 2001). None of the analyses of university-industry group effort has questioned the model of a linear pathway to development through the promulgation of university-industry partnership.

The encouragement of university-industry linkages

In the last two decades, the Mexican government has attempted to support the development of technological capabilities of firms by encouraging interaction with public universities and research centers (Casas & Luna, 1997; CONACyT, 1995, 2002; OECD, 1997b). Efforts have focused on reforming the higher education system and developing programs and institutions, mostly managed through the National Council for Science and Technology (CONACyT), that use federal funds and grants from international development organizations to support collaboration between academic institutions and firms.

The core of the reform of the higher education system in the early 1990s was a shift of emphasis from planning to evaluation as the main criteria for regulating the system (Casas & Luna, 1997; Kent & De Vries 2002). This measure was an indirect attempt to stimulate university-industry collaboration through two mechanisms. First, emphasis on evaluation affected the criteria on which governmental funds were allocated among public universities. Increasingly, government policies have tied the release of research funds to the university, to its development of projects useful for industry (Arocena & Sutz, 1999; Luna, 1997a). Second, through this action, the government has forced universities to seek external sources of income,

and thereby encouraged them to carry out research work financed by industry (Luna, 1997a).

These efforts have been complemented by the creation of mechanisms, mostly programs and institutions within CONACyT and other branches of the government, which have directly or indirectly supported the collaboration between the academic and productive sectors. Within these programs, collaboration has usually been defined as the fomentation of research alliances with the aim of developing or improving products and processes, as well as providing specialized technological services to address the needs of firms.

Outcomes

The academic sector has shown some responsiveness to stimuli intended to foster university-industry collaboration, and has gradually overcome ideological barriers against cooperating with industry that prevailed during the 1960s and 1970s (de Gortari, 1997). Within some universities, a growing interest in collaboration has been manifested through the creation of departments aimed at supporting technological programs, a review of the normative framework that regulates consulting and services between academicians and industry, and the creation of committees in charge of the operation of projects with industry. This has been the case, not only for the National Autonomous University of Mexico (UNAM), which has the longest tradition of industry collaboration, but also for other large federal and state universities that have introduced these type of institutional changes since the early 1990s, including the Autonomous Metropolitan University (UAM), and the Autonomous University of Nuevo Leon (Luna, 1997b, 2001). In general, the last twenty years have seen an increase in university-founded organizations intended to foster and manage relations with firms in a much more institutionalized way than before (Arocena & Sutz, 1999; Casas, 1997, 2001; Gortari, 1997).

Assessments of the collaborative programs that have been implemented, however, make it clear that industry participates infrequently, and that mechanisms to foster university-industry relations have been largely unsuccessful due to both a lack of demand and a lack of scope. Research on these programs has typically consisted of a collection of individual cases in which the criteria for success is based on the completion of specific projects. Information gathered through these efforts, however, is not systematic and is generally very diverse in scope, resulting in minimum utility for larger scale analysis (e.g., Asociación Nacional de Universidades y Institutos de Educación Superior (ANUIES), 1999; CONACyT, 2000). When individual programs have been successful and have been able to contribute to increasing the technological capabilities of specific firms, however, they have had limited or no impact beyond the immediate relationship (Sutz, 2000). Unsuccessful stories have generally not been investigated or documented.

According to Sutz (2000):

These micro-strengths are detected because they produce an innovation: they are by definition technically successful. Their contribution to the social accumulation of knowledge must, however, be analyzed case by case. Many times, even if the solutions found could be easily expanded to a whole industry, it does not trespass the walls of the firm participating in the experience. The reasons behind the social weakness of strong technical successes are related to the inability of the actors involved to produce expanding virtuous circles on their own (p. 283).

Another aspect of the drive for university-industry collaboration that has generally not been considered is the potential for deleterious consequences above and beyond the intended results. The mechanisms implemented to increase the participation of the private sector in funding R&D activities has induced universities to be more willing to collaborate with industry, increasing the number of business consulting missions they perform. It has also, however, induced them to reduce the amount of basic research they

carry out (Casas & Luna 1997; Katz 2000). As such, the new mechanisms for the distribution of research funds may have potentially negative effects in the long term.

The transference of knowledge through the absorption of highly trained individuals by industry has not received a great deal of attention in the case of Mexico. Evidence strongly suggests, however, that highly skilled manpower is sub-utilized by Mexican industry. In a historical review of the contribution of universities to the Mexican development process, Lorey (1993) argued that until the late 1950s, the expanding industrial and commercial sectors and the growing government apparatus easily absorbed the bulk of the universities' production of professionals. Demand for a steady supply of scarce professionals was reflected in high wages for professionals in both public and private sectors. After the 1950s, however, there was a decline in the ability of the economy to produce jobs, and a growing majority of students with aspirations to professional work and status could not be employed as professionals. Lorey sustains that since then, the Mexican government has played the role of "employer of last resort" of highly trained manpower, and attributes these results to the poor innovative performance of industry:

> …the Mexican economy did not forge an industrial plant characterized by innovation and competitiveness in the world market and did not create an independent capital-goods and research and development infrastructure. Without innovations in the machinery used in manufacturing or an increase in expenditure for research and development, the education and employment of professionals could undergo no dramatic structural change. These factors had the greatest impact on professionals trained in engineering, business, and the sciences" (pp. 168-169).

Data support Lorey's characterization of the government as an "employer of last resort." In 2000, only 19 percent of highly trained human resources working in research and development activities in Mexico worked in a position related to the productive sector. Forty-four percent, on the other hand, worked for the government. In South Korea, another late industrializing country, 68 percent of these human resources are involved in the productive sector (CONACyT, 2001; Valenti, Varela & Castillo, 2000).

A recent study conducted by the Economic Commission for Latin America and the Caribbean (ECLAC) found that Mexico's inability to absorb increasing supplies of highly qualified technical and professional workers, even during relatively high-growth periods, is representative of similar patterns across Latin America (ECLAC, 2002). The study documented a trend away from salaried positions in industry for highly qualified workers and an increase of concentration in lower-paying tertiary activities, largely in services. In 2000, 58 percent of highly skilled Mexican workers, defined as having technological or professional training, were employed by the government, or in social, community, and personal services. Twenty-three percent were employed in the commerce, energy, transportation, communications, finance, and insurance sectors. Only 19 percent were working in agriculture, mining, industry and construction. The 58 percent of skilled workers concentrated in governmental, social, community and personal services were on the average paid at the lowest level, 6.4 times the level of poverty. This compares to 11.3 times the level of poverty in agriculture, mining, industry and construction, and 13.7 times the poverty level in financial services and the insurance sector.

These failures to foment productive university-industry collaboration in Mexico have largely been explained by the low intensity and lack of coordination of the relations between universities, the government, and firms, as well as through critiques of each sector (Casas, 2001; Casas & Luna, 1997). Criticisms of Mexican universities have stressed the low quality of

human resources produced by the universities, a small academic scientific community, a small number of graduate programs offered, a lack of funding, scarce production of scientific and technical industry-relevant knowledge, and rigid and bureaucratic structures (Castaños-Lomnitz, Didriksson & Newson, 1998; National Science Foundation, 2000; Valenti, Varela & Castillo, 2000; World Bank 2000).

So far, however, more than the inadequacy of knowledge produced in universities and the lack of coordination among actors that promote collaboration, the main constraint to developing linkages with industry may involve the increased reliance by domestic firms on external sources of technology as a response to trade liberalization, market deregulation, and privatization of economic activities. The following section reviews this deintensification of the use of local engineering, highly qualified manpower, and technological capabilities by Mexican firms since the mid-1980s (Katz, 2001).

Industry and knowledge in Mexico

Mexico's modern economic history is typically divided into two periods: the import-substi-tution industrialization model and the export-oriented model.

From import-substitution to export-oriented industrialization

Prior to the 1980s, the Mexican government carried out an economic policy, known as Import-Substitution Industrialization (ISI), that focused on the shielding of Mexican industry from external competition with the goal of developing upstart industries into productive sectors capable of substituting domestically produced commodities for imported non-durables. In the early 1980s, the Mexican government abandoned this strategy and adopted a different path to economic development. The new model implemented was constructed on the premise that within a market-oriented production system, export performance –particularly of manufactured goods– is positively associated with economic growth (Balassa, 1981; Srinivasan, 1985; World Bank, 1987). It also assumes that state interventions, as in the case of ISI, result in market distortions, high economic and social costs, and an overall failure in most developing countries linked to these policies since the 1960s. Export-oriented industrialization (EOI) was a significant aspect of the so-called Washington Consensus (Williamson, 1990), a set of policy and economic reforms implemented in Latin America with the support of the World Bank and the International Monetary Fund.

The implementation of changes in industrial and R&D policies within the EOI strategy are particularly relevant to understanding the economic environment in which firms operate in Mexico. The implementation of the EOI strategy brought with it drastic reductions in trade barriers, domestic and external financial liberalization, a minimalist role for the state, and restrictive monetary and fiscal policies. The assumption behind this strategy was that macroeconomic policies aimed at generating a market-friendly environment would induce sectoral growth and development. As a consequence, the domestic industrial policy from the ISI period that consisted of price controls, subsidies, state intervention, and direct state ownership in firms and sectoral programs, was abolished in favor of "neutral policies" that treat all firms and sectors equally and avoid any form of selection and subsidies (Dussel Peters, 2000).

During the ISI years a large number of public R&D and engineering centers emerged in Mexico. Public agencies took an active role during these years in training human resources, designing and financing large-production facilities, and developing the national scientific and technological infrastructure (Amsden, 2001; Cimoli, 2000). Despite these efforts, a significant flow of innovation and knowledge development from these institutions failed to reach the private sector. According to Katz (2001), through the

ISI period, the Mexican R&D system, as in the rest of the Latin America, was "highly fragmented in nature, lacking in sense of purpose and depth. In the final analysis, it failed to serve as the true 'engine' for growth in the domestic environment" (p. 6).

In shifting to the EOI model, planners sought to spur increases in the competitiveness of Mexican firms by supporting increased R&D expenditures. Institutionally, an attempt was also made to provide for adequate protection of intellectual property rights in order to stimulate knowledge creation. Intellectual property rights have been strengthened through changes in patent law, which now allows the registration of patents in fields such as pharmaceutical products, genetics, and software. Property rights on natural resources, such as timber and water rights, have been deepened and consolidated (Cimoli, 2000).

In practice, public policy in the field of R&D has shifted from supporting public R&D conducted in labs, institutes, and universities, to financing firms in order for them to search for cheaper and better technology providers (Katz, 2001). Funds for R&D, however, have not increased substantially in the last decade, and the R&D system remains largely uncoordinated and under-funded (ECLAC, 2002).

The effect of structural reforms on the creation of indigenous knowledge

Although the impact of adapting the new model for economic development in Mexico has not been fully assessed, knowledge gaps do not seem to be getting any smaller. While the modernization of plants and equipment has, in some cases, resulted in improved technological performance, the ability of the vast majority of Mexican firms to generate technological knowledge has diminished as a consequence of the recent trade liberalization and market deregulation efforts. This, in turn, has hampered the productive sector's ability to develop linkages with other firms and domestic institutions (Casas, 1997; Cimoli & De la Mothe, 2001; Dussel Peters, 2000).

According to Dussel Peters (2000), transnational companies (TNC) have been relatively successful in integrating part of Mexico's economy into the North American market. Economic liberalization has opened the door for Mexican affiliates of TNCs, particularly in the automobile and electronics industries, to benefit from investment, modernization efforts, and the intensification of already existing intrafirm and intraindustry linkages. Most of this integration, however, has occurred in relatively low value-added, capital-intensive activities. Apart from these TNCs, however, the large majority of firms do not possess the know-how to close knowledge gaps that would allow them to integrate themselves into global commodity chains and networks.

Katz (2001) identifies the following changes in the productive sector in Mexico caused by the structural reform of the last two decades:

1) Trade liberalization has made imported capital goods cheaper than before. Hence, firms have substituted inexpensive imported capital goods for locally produced equipment and 'in house' engineering efforts aimed at expanding the life cycle of capital equipment. As a consequence, the local capital goods industry has suffered a major setback and engineering departments of many industrial firms have stagnated.

2) The privatization of state enterprises in areas such as energy production and telecommunication services has also led to the shuttering of local R&D and engineering departments. These formerly state-owned enterprises, now operated by subsidiaries of large enterprises from advanced economies, are modernizing the domestic infrastructure on the basis of imported capital equipment and engineering know-how that comes primarily from abroad.

3) Subsidiaries have also reduced 'adaptive' engineering efforts that are no longer nee-

ded since they have now become part of a global network in which 'worldwide standard designs' are being produced. Industrial firms have reduced 'in house' design capabilities as they now import parts and components and employ 'on line' foreign engineering services.

According to Katz (2001):

Both in the case of the privatization of state enterprises and in the expansion of domestically owned conglomerates in the resources processing industries, the erection of new production capacity closer to the international technological frontier has occurred on the basis of imported machinery and equipment. In such cases, we find that we are moving towards technologically more complex economies but simultaneously becoming less intensive in the use of local engineering and technological capabilities. Human capital … has become obsolete and is being replaced by imported machines 'embodying' more contemporary production techniques. A similar process would appear to be taking place in the case of domestic subsidiaries of large transnational corporations were the need for adaptive technological efforts seems to be much less significant today than decades before (p. 17).

What does this mean for university-industry linkages? Generally, firms in Mexico seem to be less interested in conducting or collaborating in joint R&D activities. Those who have successfully increased their technological capabilities appear to have largely done so through forging or intensifying already existing links with firms and academic institutions abroad (Cimoli & De la Mothe, 2001). Both of these phenomena, however, raise questions about the role of the Mexican university as a collaborator with industry in the innovation process.

Challenges for the future

The picture that has emerged in recent years, therefore, is one in which universities are being prodded strongly to operate in a manner more congruent with the demands of the market economy. Their future, particularly in terms of the availability of funds for research, seems increasingly dependent on the ability to adapt to the needs of the productive sector. Industry, on the other hand, is responding to a new macro economic environment by following a pattern of acquisition and development of technological knowledge in which the vast majority of firms have increased their dependence on external sources of knowledge and reduced interaction with local institutions. An elite group of firms, largely affiliates of transnational corporations, has developed linkages abroad through their integration with parent companies.

Thus, the academic and productive sectors in Mexico appear to be moving in different directions. The strategy of the Mexican government to bring these two paths together, as described above, remains focused on stimulating innovative performance among firms through market mechanisms. From this perspective, the university can play a fundamental role in developing the technological innovations and technologies that power regional economic growth. Evidence from recent analyses, however, cast doubt upon the likelihood that this linear process will bring universities and industry together in a manner that impacts innovation processes meaningfully, despite initiatives that encourage collaboration.

An alternative conceptualization of institutional roles in the innovation and development process can be found in National Innovation Systems (NIS) approaches. These approaches, which conceptualize innovation as the result of interactions between the firm and other institutions, such as universities, were initially utilized to understand university-industry collaborations in advanced industrialized economies. NIS perspectives have also been applied in the context of developing economies. The next section reviews these approaches and discusses their viability for the case of Mexico.

National Innovation Systems (NIS)

The National Innovation System's approach, with pioneering works by Freeman (1987), Lundvall (1993), and Nelson (1993), among others, has emerged as a central perspective for understanding university-industry relations and the technical innovation process in developed economies. Although there is no single accepted definition, most conceptualizations of a NIS build on the following assumptions hold that: 1) knowledge and innovation are the key forces determining the competitiveness of firms and countries; 2) innovation and technical progress are the result of a complex set of relationships among actors producing, distributing and applying various kinds of knowledge; and 3) the innovative performance of an economy depends to a large extent on how these actors relate to each other as elements of a collective system of knowledge creation and use. Such systems, frequently referred to as national innovation systems, are primarily –although not exclusively– composed of enterprises, universities, and research institutes (Nelson, 1993). According to the NIS view, policy-making should be directed at encouraging the development of linkages among these actors to enhance a nation's competitive performance (OECD, 1999). In the following discussion, the term "national innovation systems approach" (NIS) will be used to refer to this analytical approach, whereas the term "innovation system(s)" will refer to the actual system composed of different actors that intervene directly or indirectly in the generation of technological innovations in a country.

Developed and diffused primarily by academicians, the NIS approach and its strong policy-oriented nature has appealed to policy-makers. Within OECD countries, it has been generally acknowledged that R&D policies are country-specific and path-dependent, and that they tend to be more effectively managed with the guidance of a system perspective (OECD, 1997). In practice, the NIS approach has provided an analytical framework suitable to conduct concrete empirical and comparative analyses for the design of specific policies in the fields of R&D and innovation in economically advanced countries. Specific policy recommendations that stem from the NIS perspective have generally been developed through analyses based on the collection of information at the firm level, through case studies or indicators and surveys that help to explain aggregate phenomena.

NIS and university-industry collaboration

Research from an NIS perspective has focused on the ways in which university science contributes to technical advance in industry, and the ways in which technical advance in industry contributes to fundamental understanding (Nelson, 1994). These entities are viewed as interrelated, and the distinction between academic science and technological advance in industry is blurred. This view emphasizes the need of coordinated government intervention to clear the channels through which knowledge flows between the productive and academic sectors in order to strengthen the networks that support technological innovation (OECD, 1999). It tells little, however, about the specific role of the university in the innovative process. According to Florida and Cohen (1999), this view "fail[s] to fully grasp the objective function of the university, the intricate and complex ways in which the university is embedded within economy and society, and the full nature of the tensions thereby generated" (p. 592).

While NIS approaches have been more successful in incorporating the influences of culture and national institutional infrastructure into their analysis, they have not raised the question of how and to what degree university-industry collaboration efforts fit into different stages of the development process. In effect, NIS approaches have been used as a reference framework to design policies aiming at intensifying university-industry collaboration (OECD, 1999). While this approach has been relatively uncontroversial in

the advanced industrial contexts of Western Europe and the United States, its relevancy to developing economies like Mexico is not as clear.

NIS and developing countries

Perhaps the main drawback of the NIS approach in a country like Mexico is that it provides little insight on how to *create* an innovation system that effectively incorporates *national* actors, such as universities. While NIS systems have effectively been incorporated into analysis of strong diversified economic systems with well developed institutional and infrastructure support of innovation activities, the relevancy for system building remains undemonstrated (Lundvall, Johnson, Andersen & Dalum, 2001).

In more developed OECD countries, innovation systems have been evolving over time as countries have industrialized. Prior to the 1980s, the role of science for technological innovation was traditionally mediated through various channels, including labor mobility and informal relations between the academic and productive sectors. It was only in the 1980s that policy makers in these countries recognized the need for *purposeful coordination* to improve overall domestic innovative performance. This came to be, at least partially, as a response to the challenges imposed by specific events such as the successful emergence of Japan as a super power in the international market, the rapid development and dissemination of information and communications technology, and the lagged growth of their own productivity despite large investments in new technologies (Shulin 1999). In these cases of developed economies, different combinations of government intervention and market mechanisms were applied at both the national and the firm level to forge national systems of innovation.

Most researchers involved in the development of the NIS approach, and policymakers who have been their main audience, have been specifically interested in the structure and dynamics of *national* systems. This fact reflects a belief that the innovative prowess of national firms is determined to a considerable extent by government policies and by the functioning of domestic institutions, which in turn influence factors such as intellectual property rights, standards, capital and labor market regulations, and contract laws. The possibility, however, must be considered that the concept of a *national* system of innovation is becoming less meaningful as cross-border linkages and information flows increase along with the internationalization of corporate R&D (Patel & Pavitt, 1998).

In the case of Latin American economies, the impact of trade liberalization and of deregulation and privatization of economic activities that has taken place over the last two decades has resulted in increased interconnectedness with institutions and firms abroad and less responsiveness to domestic incentives for collaboration. Mexico is a prime example of this phenomenon. According to Katz (2001), "…the change in the global incentive regime has blurred the limits and national identity of the various local innovation systems, enhancing the role played by external firms, institutions and sources of know-how" (p. 18). If the NIS perspective is to be used to analyze developing economies, more research on the impact of globalization processes on system building in developing countries and the relationships between globalization and national-local systems is needed.

Another important criticism of the NIS approach is, paradoxically, its lack of system-level explanatory analysis. Typically, scholars have focused on the roles of specific actors and the impact of specific policies and institutions, but have not provided system-level descriptions of the national systems' structural dynamics of performance. This has limited their ability to develop comparisons with non-OECD countries or regions that have very different starting conditions or to develop alternative system structures to accomplish technological innovation. The NIS approach has yet to explore the possibility that alternative system structures may be neces-

sary to achieve technological innovation in economies with very different starting conditions, including but not limited to central planning and functionally specialized organizations, for example (Liu & White, 2001).

So far, NIS approaches have not been readily adapted to the characteristics of a late-industrializing country like Mexico, rendering the NIS reference framework insufficient to understand and encourage collaborative patterns between the academic and productive sectors in these contexts. The next section reviews alternative perspectives in the context of experiences of both developed and developing countries.

Universities and industry: lessons from experience

This section turns to experiences of university-industry collaboration in developed economies, and in late-industrializing countries in East Asia, particularly elements of these experiences that potentially serve to clarify the nature of collaboration between the academic and industrial sectors in Mexico.

Diversity of university-industry collaborative patterns

Although there is a common trend to encourage university-industry collaboration in advanced economies, the *direct* contribution of universities to industrial development varies among countries. Japan and the United States for example, contain similar industries and face many of the same challenges of harnessing scientific research for purposes of technological innovation. Yet relations between industrial firms and universities have developed quite differently in these countries. American universities have elaborated a host of formal arrangements for conducting industry-sponsored research and transferring technology to commercial applications (Feller, 1999; Rahm, Krikland & Bozeman, 2000). These types of formal arrangements are relatively rare in Japan. Japanese industry has instead met many of its technological needs through the establishment of central research institutes, while maintaining strong networks of tacit, informal relationships with academic scientists. In fact, Japanese companies seeking research partners have at times found it easier to form agreements with American universities (Pechter & Kakinuma; Peck & Tamura 1976; Rahm, Krikland and Bozeman 2000).

University-industry collaboration experiences in developed economies show that linkages between academy and industry can take many forms, be initiated in a number of ways, and take place on different scales. The specific form of collaboration developed in a country seems to be heavily influenced by the institutional framework for technological innovation, the level of technological development reached by the productive sector, and cultural and historical factors. Parker (1991) shows that great a variety of mechanisms to induce collaboration have been developed through the years. While there does not seem to be a consensus on which approaches are especially effective under a wide range of circumstances, it does seem clear that collaboration is not inherently natural for either the university or industry, and finding the adequate mechanisms is often the result of trial and error processes.

University in late industrialization experiences in East Asia

The experiences of countries like South Korea, Taiwan and Singapore provide useful insights to understand the role of universities during the "catch up" process. Evidence from these countries shows that a sustainable pace of technological development can be attained despite engaging in relatively little basic research and establishing few university-industry linkages (Kim, 1997; Lall, 1990). In these countries, university research has frequently been described as inadequate, insufficient, or de-linked from the needs of the domestic industry (Berger & Lester, 1997; Kim, 1997; Peck & Tamura, 1976). Economic performance has been attained through intense and coordinated efforts at acquiring advanced te-

chnologies from industrialized economies. Thus, technological prowess in these countries is not founded on conventional approaches to innovation and R&D, but instead, on a well developed system of management of *technological diffusion* that has evolved dynamically in the last decades in response to changes in industry (Mathews, 1999). These countries have aggressively encouraged R&D activities to solve individual problems with applications, and basic science has been a lower priority. Given the inadequacy of university research to meet the specific needs of a "late-comer" industrial sector, governments, have made public R&D institutes the backbone of advances in R&D (Berger & Lester, 1997; Hobday, 1995; Kim, 1997).

To what extent the lack of strong ties between university and industry impedes these economies systems from moving up the value-chain in global production is an open question. Its answer seems to be closely related to the characteristics of the R&D needed by domestic industry. Forbes and Wield (2000) argue that, given the fact that most R&D conducted in these countries is more *development* than *research*, a very new conceptualization of R&D is required in countries that perform as "technology followers." Accordingly:

Rather than pushing out the technology frontier… innovation tasks in followers should aim to approach and follow the frontier as efficiently as possible, with the objective to move the firm up the value-chain of global production by increasing productivity and making higher value products. That the future technology frontier is known to followers reduces uncertainty involved in innovation, [and] makes the innovative task different [from developed economies] (p.1096).

This form of R&D takes place primarily within the firm. The implication this conceptualization has on the role of basic research generated in developing countries' universities, however, has been virtually unexplored in the literature.

Evidence from these East Asian economies shows that as industrial progress takes place, there is still a crucial need for university participation, but rather in an indirect form, through the formation of manpower. In South Korea, for example, the lack of development in university research has been perceived as a bottleneck for industrial performance because it inhibits the development of research abilities in students that later move to the labor market (Kim, 1997). More than the research results, the main benefit from collaboration seems to be exposing students to applied research, which familiarizes them with the private sector and increases their capabilities of succeeding in this sector (Berger & Lester, 1997; Parker, 1991).

University research as an engine of economic development

Thus, the vision of university research as an engine of economic development is rather simplistic. East Asian economies have found that although there are important benefits from stimulating direct interaction between university and industry, the university has been far from playing the role of an "engine" for industrial development. Evidence from developed countries support this view. Florida and Cohen (1999) argue that:

The role of the university in economic development has captured the fancy of business leaders, policy-makers, and academics as they have looked at the examples of technology-based regions like Silicon Valley and the Route 128 region surrounding Boston and Cambridge. They have concluded that the university has played a fundamental role in developing the technological innovations and technologies that power those regional economic models. A theory of sorts has been handed down based mainly on anecdotes and so-called success stories of the university as "engine" of regional economic development… what appears to matter here –and what it is too often neglected in policy circles– is the ability of a region to absorb the science, innovation and technologies which universities generate (pp.604-605).

University-industry collaboration, therefore is not necessarily a *cause* of high levels of competitiveness in industry but instead the *result* of a combination of a variety of interconnected local elements, including adequate mechanisms to enhance collaboration, a local research community well connected with the international science community, a significant amount of technology-based firms, and a domestic R&D system focused on the demands of the productive sector, among other factors. Thus, it becomes clear that it is the pace of technological change, more than government incentives, which puts universities in the position of driving industrial growth (Branscomb, Kodama, & Florida, 1999).

Conclusions

It is widely recognized by policy-makers and researchers that if Mexico is to adopt a path for economic development characterized by the production of high value goods, it has to increase its ability to acquire, transform, and generate technological knowledge. In this context, public interest has increasingly perceived the university as a crucial source of new skills, knowledge and ideas. This has placed the research university in the role of something akin to the fuel that drives the "engine" of development.

There are two assumptions behind this expectation: first, that there is a linear pathway from university investigation to commercial innovation to regional development and widening networks of innovation; second that if institutional structures and relationships can be transformed to replicate those observed in advanced industrialized nations, innovation and expanding innovatory networks will necessarily follow.

These assumptions, however, may be of limited usefulness for the case of Mexico, and at least three important elements need to be considered while trying to conceptualize the role of university-industry collaboration in Mexico. First, although collaboration brings important benefits to the parties involved, it is not inherently natural for either the university or industry, and finding policies that encourage the development of linkages between the academic and productive sector seems to be the result of a trial and error process.

Second, collaboration is not a static concept. Instead it evolves over time and is influenced by cultural and institutional factors that also influence the industrial development process. More research is needed to understand how and to what degree university-industry collaboration efforts fit into different stages of the development process of particular economies.

Third, the vision of university research as an engine of economic development is rather simplistic. More than a *cause* of potentially high levels of competitiveness in industry, university-industry collaboration is more the *result* of a combination of a variety of interconnected local elements. Hence, rather than being a final recommendation, university-industry collaboration in the Mexican context, is the beginning of a little explored research path that demands innovation in policy making and reflective thinking.

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