Industry-University Collaboration in Developed and Developing Countries

by

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Report No.: 11374 Type: (MIS) Title: INDUSTRY UNIVERSITY COLLABORAT Author: PARKER, LINDA Ext.: O Room: Dept.: PHREE PAPER SEPTEMBER 1992

Education and Employment Division
Population and Human Resources Department
The World Bank

September 1992

This publication series serves as an outlet for background products from the ongoing work program of policy research and analysis of the Education and Employment Division in the Population and Human Resources Department of the World Bank. The views expressed are those of the author(s), and should not be attributed to the World Bank.
The International Bank for Reconstruction and Development/
The World Bank, 1992
ACKNOWLEDGEMENTS

More than anything else, assembling a document like this involves obtaining tidbits of information from many people. In this regard, I would like to thank especially Tom Eisemon, Jeremy Oppenheim, the Science Policy Support Group - International Study Group on Academic-University Relations, and Henry Etzkowitz. Florence Heckman always had the documents that I needed, no matter how obscure. Tom Eisemon, Carlos Kruytbosch, Kin Bing Wu, Halsey Beemer, Maurice Boissiere, Vaughn Blankenship, and Arnoldo Pirela made valuable suggestions and corrections to various drafts. Finally, Erik Thulstrup provided both the opportunity to write the paper and consistently practical suggestions for making the project manageable. His thoughtful reading of the first draft and continuous search for interesting models to include injected clarity and variety.
ABSTRACT

Over the past three decades, developed countries have experimented with different ways of using scientific research and technological development to promote economic growth. One means is through establishing industry-university research collaborations. In recent years, the number and variety of linkage mechanisms in developed countries has grown rapidly. Developing countries are also increasingly involved in fostering collaborations. At present, there is no consensus regarding which mechanisms are effective and under what circumstances. This paper examines a variety of models in use and lessons learned through trial and error, first for developed countries, then for developing countries. Finally, it explores ways to gauge a country's readiness for collaboration.
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<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>CIT</td>
<td>Center for Technological Innovation</td>
</tr>
<tr>
<td>EAJ</td>
<td>East Asia and Japan</td>
</tr>
<tr>
<td>EC</td>
<td>European Community</td>
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<tr>
<td>EPSCoR</td>
<td>Experimental Program to Stimulate Competitive Research</td>
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<td>ERC</td>
<td>Engineering Research Center</td>
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<tr>
<td>FWT</td>
<td>Fund for World-Class Technology</td>
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<td>GNP</td>
<td>Gross National Product</td>
</tr>
<tr>
<td>IDB</td>
<td>Inter-American Development Bank</td>
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<td>ITRI</td>
<td>Industrial Technology Research Institute</td>
</tr>
<tr>
<td>ITTU</td>
<td>Intermediate Technology Transfer Unit</td>
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<tr>
<td>I/UCRC</td>
<td>Industry-University Cooperative Research Centers</td>
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<tr>
<td>KAIST</td>
<td>Korea Advanced Institute for Science and Technology</td>
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<td>KOSEF</td>
<td>Korea Science and Engineering Foundation</td>
</tr>
<tr>
<td>MITI</td>
<td>Ministry for Technology and Industry</td>
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<tr>
<td>NIC</td>
<td>Newly Industrialized Country</td>
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<tr>
<td>NSB</td>
<td>National Science Board</td>
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<td>NSF</td>
<td>National Science Foundation</td>
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<tr>
<td>OECD</td>
<td>Organization for European Cooperation and Development</td>
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<tr>
<td>OTA</td>
<td>Office of Technology Assessment</td>
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<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
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<td>RD&amp;E</td>
<td>Research Development and Engineering</td>
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<tr>
<td>RF</td>
<td>Revolving Funds</td>
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<tr>
<td>S&amp;T</td>
<td>Science and Technology</td>
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<td>SEIP</td>
<td>Science-Based Industrial Park</td>
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<tr>
<td>SME</td>
<td>Small- and Medium-Sized Enterprises</td>
</tr>
<tr>
<td>SRC</td>
<td>Science Research Center</td>
</tr>
<tr>
<td>STDB</td>
<td>Science and Technology Development Board</td>
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<tr>
<td>TCC</td>
<td>Technology Consultancy Centre</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>UNAM</td>
<td>National Autonomous University of Mexico</td>
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<td>US</td>
<td>United States</td>
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EXECUTIVE SUMMARY

Until recently, the important connection between, on the one hand, scientific research and technological development and, on the other, industry and economic development has had little impact on countries' science and technology (S&T) policy. Industrialized countries have been slow to encourage collaboration between the two communities that are most likely to connect S&T with economic development: universities and industries. In some countries, this is due to the fact that researchers based in universities or research institutes traditionally have had few incentives to collaborate with researchers in industry, or there have been strong cultural or legal reasons for the lack of collaboration. On another level, collaboration has not always been necessary. Many technological advances that have led to fundamental societal changes have been discovered in the absence of a complete scientific understanding of the advance itself.

In developed countries collaborative relationships have been considered at best peripheral to the main higher education missions. More frequently, they have been looked upon by students and faculty members as simply undesirable and not appropriate. In recent years, however, financial need on the part of universities has caused a notable change in the desirability of interaction. Industry is also increasingly aware of the cost-effectiveness of access to university research facilities, students, and personnel. While there are cases in which collaboration has been active for many years, major attention to the possibilities of such interactions came about only in the 1980s.

Developing countries are only beginning to explore these relationships. Those with universities that conduct some research and industry that can profit from research-based technological development are in position to engage in mutually beneficial linkages. Some are experimenting with ways to foster joint research activities. At the moment, there is little consensus on which approaches are especially effective under a wide range of circumstances.

There are a number of reasons for engaging in industry-university collaboration. One of the most important is exposing students to the needs of industry and giving them experience in conducting research that has industrial application. The experience can motivate graduates to work in industry, which, in turn, can benefit from the knowledge, skills, and techniques students learn while in school. This diffusion effect is crucial in developing countries if they are going to make economic progress through technological advances.
This paper examines a variety of mechanisms currently in use in developed and
developing countries, factors that influence success, and lessons learned from experiences
in both groups of countries. Given the breadth of the topic, there has been no attempt to
be comprehensive. Emphasis is on building research collaborations in the physical sciences
and engineering. The following topics have been excluded: agriculture and health,
collaborations between research institutes without university connection and industry,
aquisition of imported technology unless it is needed for industry-university research
linkages, intellectual property rights issues, industry-university collaboration that focuses on
building businesses, S&T policy or brain drain issues, and technology innovation outside of
the context of collaboration.

Several conclusions emerge. First, industry-university collaboration cannot be
successful in the absence of a variety of interconnected elements, regardless of the specific
characteristics of any particular collaboration model. On a fundamental level, there must
be universities with appropriate research facilities, faculty members who can perform
research, industry that is willing and able to make use of the results of joint activities, and
incentives for both parties to collaborate. At a higher level, government policies, programs,
and expenditures play crucial roles in determining the extent to which the basic elements
are present and the extent to which collaboration is likely to occur and be successful.
Government involvement can be instrumental in the development of successful
collaboration; it can also stifle it. Models described in this paper illustrate the difficulties
that countries have in determining the appropriate amount and type of government control
over the development and functioning of these elements in the face of competing economic,
social, and cultural influences.

The second conclusion is that the concept of industry-university collaboration assumes
adoption of at least some of the values and norms associated with Western universities. An
institution without professors trained to conduct research, some level of research facilities,
graduate programs, or academic freedom is unlikely to be in a position to engage in fruitful
research collaboration with industry. Nonetheless, excessive adherence to Western norms
and values can discourage collaboration with industry, thereby limiting the role that
universities play in economic development.
Finally, the existence of industry-university collaboration may be more important than the mechanism used or the utility of the research results. Collaboration is necessary for its symbolic quality: it sends a signal to faculty members of the value of doing work that relates to economic needs. It also provides industry with trained workers who are familiar with, and ready to work in, the private sector. Taken together, these outcomes can have a remarkable impact on a country or region.
I. BACKGROUND

I.1. Barriers to Collaboration

Developing countries encounter a variety of barriers to collaboration. One source is the academic culture often adopted from Western (developed) countries. The goals, value system, methods of operation, and reward system that many developing countries have adopted from Western universities conflict with the needs of developing countries, as well as the culture of industry that developing countries are trying to establish (Blais, 1990; Jones, 1971). Academicians who received research training in developed countries may be even more reluctant than their colleagues in countries to engage in research geared to local needs if they have accepted the Western values of basic research and participate in international scientific networks. The result can be particularly strong biases against involvement with the practical problems faced by industry (Jones, 1971).

Mexico provides other examples of how values and conditions can inhibit collaboration. First, the social image of science and technology does not place researchers in an important social position. Second, there is basically no industrial research and development (R&D) activity in the country and many good researchers stay abroad after completing scientific training to take advantage of greater opportunities. Third, until recently, university researchers' salaries have been too low for them to be able to conduct research actively. Taken together, there has been little reason or opportunity for performing research, much less collaborating with industry (Soberón and Rodríguez, 1991).

In developing countries, professors are often government employees on 12 month contracts. As a practical matter, regulations often prohibit them from earning money for conducting research for industry as a consultant. Thus, even when industry is interested in making use of professors' research expertise, it may be illegal for research services to be remunerated. This arrangement provides little or no flexibility for conducting research.

Besides the lack of national tradition of collaboration or awareness of its value, another obstacle is the perception that collaboration will threaten traditional academic values. Some faculty members and university administrators are afraid that industrial collaboration will endanger their institutions' basic research and graduate training missions (Bollag, 1990; Fairweather, 1990). Similarly, university researchers are sometimes concerned that engaging in industry-sponsored or applied research will be of no benefit, and possibly hurt, their career (NSB, 1982). The career constraint problem stems from the academic
reward structure not placing as much value on research with industrial or practical relevance. Another perceived threat to academic values is that industrial influences will restrict academic freedom, especially when intellectual property rights conflict with traditional dissemination of knowledge (Berman, 1990; NSB, 1982; Van Dierdonck and others, 1990).

The reward structure in universities in many developing countries is based on promotion criteria that are easily counted, e.g., publications. While this may not send signals that encourage collaboration with industry, it is a means of rewarding performance in a meritocratic fashion when a country is multicultural.

The following table gives a sense of the range of differences between academic and industrial research:

<table>
<thead>
<tr>
<th>Typical Aspects</th>
<th>University</th>
<th>Industry</th>
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<tbody>
<tr>
<td>Focus of the R&amp;D</td>
<td>Basic research; curiosity-oriented</td>
<td>Applied research; experimental development</td>
</tr>
<tr>
<td>Basic rationale</td>
<td>Advance knowledge</td>
<td>Increase efficiency</td>
</tr>
<tr>
<td>Aim</td>
<td>New ideas</td>
<td>Profits</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Idea-centered</td>
<td>Practical; product-centered</td>
</tr>
<tr>
<td>Framework</td>
<td>Open</td>
<td>Closed, confidential</td>
</tr>
<tr>
<td>Evaluation</td>
<td>By peers</td>
<td>By the boss</td>
</tr>
<tr>
<td>Schedule</td>
<td>Open-ended</td>
<td>Tight, predetermined</td>
</tr>
<tr>
<td>Recognition</td>
<td>Scientific honors</td>
<td>Salary increases</td>
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Barriers are not one-sided. As has been the case in Mexico, industries in developing countries often engage in little if any research. Reasons for this include (Dahlman and Brimble, 1990):

- no immediate need;
- little or no incentive for firms to compete;
- sophisticated technology is imported as turnkey package deals;
- firms in international joint ventures rely on R&D of parent firms; and
- small firms cannot afford to pay for R&D.

The size of a firm affects the ease with which collaboration can develop. University researchers may not be interested in cooperating with small firms because they tend to be interested in problems that are not enough of a challenge to academic research. Additionally, small firms often lack adequate in-house research organizations or personnel to build a linkage and funds to pay for university research. Small high-tech firms, however, are an exception (NSB, 1982).

If industries see little reason to invest in R&D and universities perform basic research with minimal relevance to the needs of the productive sector, the likelihood of collaboration is low (Dahlman and Brimble, 1990).

Finally, industry-university collaboration is not inherently natural for either party. One notable stumbling block is the "we haven’t done this before" syndrome. A variation from industry’s perspective is that, until collaboration with academia is tried, no one can see what good “outsiders” can be to the firm (McHenry, 1990, p. 40). Nonetheless, resistance tends to lessen once both parties try working together and learn how to operate in each other’s environment (Van Dierdonck and others, 1990).

I.2. Regional Models

The paths that some clusters of developing countries have taken to build higher education systems and R&D capacity have decidedly regional characteristics. This section constructs profiles of R&D and higher education development in selected regions. History, especially the nature of contacts with and influences of developed or metropolitan countries, plays a profound role. Regional approaches are reflected in: (1) when and how higher education and academic research are strengthened; (2) the focus and role of academic research; (3) the role of government in higher education and R&D; and (4) barriers to building capacity. As with all profiles, they are generalizations. Exceptions certainly exist; nonetheless, it is useful to examine the key elements of each profile prior to looking at specific collaborative mechanisms.
12.1. *South East Asian Profile*

There are three basic elements to the South East Asian model. First, constituent countries are guided by the Japanese approach to economic development. Second, there are actually two groups of countries within the South East Asian group: the Newly Industrialized Countries (NICs) and another group consisting of countries that have made less progress than the NICs. The NICs include Taiwan, Hong Kong, South Korea, and Singapore, while the other group contains Thailand, Malaysia, the Philippines, and Indonesia. Third, the NICs have achieved rapid technological development despite engaging in relatively little basic research and establishing relatively few industry-university linkages.

The Japanese approach is characterized by movement from a "catch-up" phase, which involved the absorption of technologies from developed countries, to a phase in which the Japanese developed autonomous technologies. The role of R&D was to solve individual problems with applications. Basic science had clearly lower priority. Beginning in the late 1980s, the country's priorities shifted. This change reflected an awareness of the importance of basic research, and that the country had neglected it while in pursuit of technological advancement (Okamoto, 1991).

Consistent with the Japanese approach, basic research capacity in all South East Asian countries is limited. On a less formal basis, academic researchers engage in consultancies with industry (BioTechnology International, 1990). It appears that the NICs chose to build technological capacity, at least up to a certain point, prior to building basic research capabilities and increasing productivity. Initially, emphasis was on topics with indigenous relevance and importing and exploiting existing technologies. In time, the emphasis broadened to include some level of basic research and developing indigenous technologies (Ranis, 1990). To address the deficiencies of academic research, these countries have built government-industry research centers. In some cases researchers are academics. In others, the centers and researchers have no ties to universities (BioTechnology International, 1990; Sigurdson and Anderson, 1991). Regardless of where they work, many receive their research training abroad. Again following the Japanese approach, South East Asian countries have for years relied heavily on other countries for provision of the training that is essential for technology adaptation (Thulstrup, 1992).

Once NICs set about to increase research productivity, progress is rapid. According to Coward (1990), Taiwan and South Korea increased the number of papers in international journals at least 50% from 1985 to 1988. The increases were not due to excessively small
numbers in 1985. In fact, the countries had the highest numbers of articles in 1985 and experienced the largest percentage increases in the region. Despite these advances, it does not appear that South East Asia is working consistently toward developing a top quality scientific community. The preference seems to be for a scientifically literate citizenry and focused expansion of basic research capacity to feed into existing industrial emphases and for training graduate students (Ranis, 1990).

From a bibliometric standpoint, China is considered a NIC (Coward, 1990). However, unlike other South East Asian countries, it has followed the same course as India and provided vigorous support for basic research.

Other South East Asian countries -- Thailand, Malaysia, Philippines, and Indonesia -- also increased research productivity, but the numbers and percentages were noticeably smaller than those for the NICs. The difference is so large that Thailand, the most productive among the second group in 1985 and 1988, accounted for less in both years than the smallest and least productive NIC, Singapore (Coward, 1990). The latter, however, does not take into consideration the fact that Singapore has more scientists per 10,000 people than does Thailand.

While research productivity increases among NICs are impressive, it is unclear how the match between industry needs and university research will develop. Nonetheless, the role of university-based research in the NICs differs from that in developing countries in other regions, as well as in many developed countries. Despite building the capacity of academic science, NICs are unlikely for some years to become significant forces pushing out the frontiers of science. Their primary focus will remain creating institutions and incentive systems that link applied research with technological advancement for the sake of economic expansion (Rosenberg, 1990).

1.2.2. Latin American Profile

Most Latin American countries have centralized R&D systems. Many have been in existence for decades. Political and economic difficulties have lead to erratic support for government-dominated R&D, emigration of researchers, and, in some cases, solicitation of research support from industry (Ailes and others, 1988).

Practically all of Latin American science is supported by national governments, but it has not been a consistent priority over time. R&D expenditures as a proportion of Gross
National Product (GNP) are low compared with developing countries in other regions of the world. Inflation, large external debt, a small scientific community, and declining opportunities to obtain higher education are hurting efforts to expand R&D capability. In some cases, government support for both R&D and higher education has been reduced (Ailes and others, 1988; Lavados, 1991; Soberón and Rodríguez, 1991).

The five Latin American countries producing the largest numbers of research papers in internationally recognized journals (i.e., Brazil, Argentina, Mexico, Chile, and Venezuela) typically emphasize basic bioscience research. They also tend to have a publication profile that resembles that of developing countries that specialize in a few fields rather than the broader profile that characterizes NICs (Ailes and others, 1988). The exception is Brazil. While most productive, it resembles NICs most closely in terms of relative numbers of publications and breadth of fields in which articles are published (Coward, 1990; IDB, 1988). Brazil's performance is due to several decades of consistent investment in R&D and strong efforts to prepare university-level research personnel (IDB, 1988).

In general, given the number of world-class researchers in Latin America, the number of publications in internationally recognized journals from the region is notably low (Coward, 1990; IDB, 1988). While these researchers were producing articles at a rate comparable to that common in the NICs in 1985, growth rates among the latter far outpaced those of the Latin American countries by (Coward, 1990). This may be a reflection of the degradation in government support of R&D in the face of the economic crises during the 1980s in many Latin American countries.

Latin America has no tradition of industry-university collaboration. R&D has been carried out almost exclusively in universities or research institutes, not in industry. Even then, it has been relatively constrained. While some universities have a long history of research, most concentrate on undergraduate teaching. In the best of circumstances, research institutes go only as far as the pilot scale level with a new idea. Some consider this type of work to be beneath the level of professional researchers. Similarly, firms have no pilot plants; they prefer to buy foreign technologies, rather than develop their own. Hence, cultural norms prevent transferring research results to firms that could use them. This represents a particular loss in biotechnology, since some countries in the region are especially strong in this area of research (IDB, 1988).

In recent years, the principal means of developing industry-university relations appears to have been the science or technology park. Brazil and Argentina have established a
number and plan others, while Mexico is developing one (Ailes and others, 1988; Blanpied, 1989; Rudin, 1990). For these and other collaborative efforts to work, some academic researchers must shed their disdain for practical application and industry must learn to look for solutions to their production problems in their country's R&D infrastructure (IDB, 1998; Waissbluth and others, 1988). If these changes do not occur, it is not clear from the region's history that it will be able to find alternative means to develop useful industry-university collaborations.

1.2.3. African Profile

The status of R&D in Africa is intimately linked with each country's colonial experience and its residue. During the colonial era, the establishment of governmental and quasi-governmental research institutes generally preceded the creation of universities by several decades. In Anglophone countries, the institutes were established by colonial governments and commodity growers (Eisemon and Davis, 1991). In Francophone Africa, the institutes were established by the French government and remained administratively responsible to France after decolonization, as well as dependent upon France for financial and research support. For many years, other Western countries, both directly and through and international organizations, have provided a large portion of R&D support to Africa for international research centers. As a result, individual African nations have had little control of their own scientific activity (Eisemon and others, 1985). Even now, many research institutes in Francophone countries depend upon France for their scientific staff and financing (Eisemon and Davis, 1991).

A few African universities were established well before decolonialization. Being patterned after institutions in the colonizing countries, they encouraged research by faculty members from the beginning (Eisemon and Davis, 1991). Modern universities were established when independence from colonial powers appeared likely. As with many developing countries, most of the domestic support for higher education has come from national governments. Degree programs resemble those of colonizing countries, and undergraduate teaching takes precedence over training graduate students (Eisemon and Davis, 1991). While universities have been the focal point for research, African countries have traditionally had notably small scientific communities (Eisemon and Davis, 1992).

The scientific culture is low, and the cultural climate is not conducive to growing S&T capacity. Science teaching is poor starting in primary school, and few opportunities exist to diffuse the culture of science into society. Governments rarely approach universities with
scientific or technological problems. Government officials are not adequately trained to recognize the scientific or technological nature of the problems. Further, due to vested interests within ministries, they may not wish to seek solutions to problems (Ayiku, 1991).

At present, most countries in Sub-Saharan Africa face a three-way dilemma: long-term shrinking of government support for higher education and research, pressures for mass undergraduate education, and a weakening of academic research capacity. Under these conditions, it is unlikely that the countries will be able to improve the quality of either undergraduate or graduate education or research significantly (Heyneman and Etienne, 1988). With government contributions for academic and non-academic R&D dropping, support in African countries comes increasingly from foreign sources. This contrasts with large increases in governmental expenditures for R&D in many South East Asian countries since the late 1970s (Eisemon and Davis, 1992).

There is little opportunity for industry-university collaboration. Industries are weak and are rarely in position to make use of research findings from universities. Research infrastructure is lacking, scientific communities are small and isolated, and there is a dearth of demand for scientific or research expertise (Muskin, 1992). Even in agriculture, lack of government support for collaboration and few incentives for both conducting research of use in the productive sector and operating extension services have resulted in few linkages (Seymour, 1991). However, an innovative collaborative approach that involves a university in Kenya, a university-based research center in Slovenia, and industry is being prepared by Kornhauser (1992).

Nigeria provides a special example of the situation in African countries. It has by far the highest most research activity. While university research has been conducted for years, little of the results have been commercialized. At the university end, the incentive structure for researchers places significant emphasis on research output and publications. Articles must appear in learned, preferably foreign, journals. Publication in local journals, of which there are few, is not rewarded, neither is unpublished work. Any technology-related work not intended for publication is considered by many to be unworthy of recognition. Thus, it is not surprising that there is little transfer of indigenous research results to production processes and commercialized products (Ogbimi, 1990).
II. CASE STUDIES IN DEVELOPED COUNTRIES

University/industry collaboration can take many forms, be initiated in a number of ways, and take place on different scales. This section presents a variety of mechanisms that have been in existence for a number of years and about which there is some operational information. It is arranged by the scale and complexity of the activities.

II.1. Research Centers Housed at Universities

II.1.1. Regional Programs within Countries

Research centers have existed at U.S. universities for over a century and even longer in Europe. Most have external support, e.g., from private foundations or the U.S. Government, and there was a rise in the number receiving support in the 1980s. One reason was that U.S. state governments developed strategies to enhance state-level economic development by supporting a variety of R&D programs, including research centers located at universities. The focus of these centers has ranged from applied research to advanced technology development. In most cases, they have university, state government, and industry support.

The high point for development of regional technology programs in the U.S. was the mid to late 1980s, during which time efforts were made to catalog programs across the country (Minnesota Department of Trade and Economic Development, 1988) and case studies were performed (Peters and Wheeler, 1988). Starting in the late 1980s, U.S. states began to experience economic downturns. Reductions in revenues have put a number of centers programs in jeopardy. It is possible to extract some lessons from this boom-and-bust experience.

David Osborne (1990) has examined a variety of programs and has identified a number of lessons to be learned. One of the biggest mistakes is for government planners to neglect a detailed study of their state’s economy on the regional and industrial levels. Many state officials moved too quickly into program planning before making an assessment of their state’s strengths and weaknesses. Programs often did not match needs. Much money and effort went into activities that were not needed, while areas needing assistance, e.g., public education and job training, were practically ignored.
Osborne (1990, p. 56) also found that programs were often not structured to become self-sustaining. To do so, the government's role becomes one of "wholesaling", meaning that a government "would attempt to use public resources and leverage to change private-sector behavior ... to nudge businesses to broaden their research relationships with academia." Osborne feels that the most popular center model, the industry-university research center, "appears to be seriously flawed" (p. 57). Academic priorities, particularly basic research and the training of graduate students, are given higher priority than the needs of cooperating businesses and government. Collaborating firms are not intimately involved in setting the research agenda. The results of this include little technology transfer, little if any impact on local businesses, but a significant number of publications.

For the time being, it may not be possible to determine the overall impact and effectiveness of regional technology-based programs. While waiting long enough for programs to have had a chance to work is important, the situation is more complex. At the apogee of development of such programs in the US, Peters and Wheeler (1988) concluded that existing analytical methods were inadequate to provide answers to the main question of whether a particular program or technology strategy affected economic development of a region.

II.1.2. National Programs

A. U.S. - Engineering Research Centers

During the 1980s, the U.S. National Science Foundation (NSF) established a number of programs that support development of university-based research centers. One of these programs, the Engineering Research Centers (ERC) program, supports interdisciplinary research that is performed collaboratively by universities and industry. The goal of the program is to bring engineering and scientific disciplines together to address fundamental research issues crucial to the next generation of technological advances using an engineering systems perspective. To accomplish this, each center must have active participation and long-term commitments from industry and other user organizations (NSF, 1988).

The program has been a model for China's and Korea's ERC programs (see discussion of Korea's program below). One of the reasons is that the U.S. ERC program incorporates a new approach to training undergraduate and graduate students. Specifically, the program aims to teach students to be comfortable using a cross-disciplinary team approach to problem solving. Students participate actively in center research at the host
institution as well as in industry laboratories, and take new courses developed directly from the content of the center's research. ERCs are supposed to develop a "new" type of engineer who is familiar with the cross-disciplinary, integrated view of technology from research to product (NSF, 1988).

B. U.S. - Industry/University Cooperative Research Centers

NSF has operated one program of centers for nearly 20 years. The Industry/University Cooperative Research Centers (I/UCRCs) differ from the ERCs in goals and scale. I/UCRC goals are (NSF, 1989):

- to develop industry, state, and other support for industry-university interaction on industrially relevant fundamental research topics;
- promote university research to provide a knowledge base for industrial and technological advancement while training students; and
- promote research centers that become self-sustaining with industry, state, and other funding within a five-year period.

While ERCs receive on average US$2 million annually from NSF and additional funds from industry, most fully operational I/UCRCs receive from US$50,000 to $100,000 from NSF and require a total of US$300,000 from at least six firms in order to have a sufficient research base. The industrial relevance and eventual self-sustaining characteristics of the I/UCRCs are noteworthy (NSF, 1989; NSF, 1988).

Two recent developments in the I/UCRC program are relevant. First, the program was modified for the 1991 competition to make state participation mandatory. Previously, state funds could have been included in the funding of a center, but they were not required. The change made it easy to incorporate the new I/UCRCs into existing state S&T strategies. It was also a response to growing criticism by states with their own programs that the growing number of Federal research centers programs that encouraged state matching funds often forced state officials to allocate funds for Federal centers that contributed little or nothing to a particular state's S&T strategy. Second, NSF has entered into agreements with a few European countries to replicate the I/UCRCs and pair the replicas with existing NSF centers with similar research direction for the sake of expanded collaboration (Schwarzkopf, 1992).
II.2. Industrial Extension Services

II.2.1. Georgia Tech Extension Service

The concept of extension services is well-established in the US. The Morill Acts of 1862 and 1890 provided Federal land for states to use for the creation of higher education institutions with curricula in which agriculture and the "mechanic arts" (engineering) were equal to science and classical studies. These institutions became known as land-grant colleges and universities. Two additional pieces of legislation, in 1887 and 1914, provided that the land-grant institutions establish agricultural experiment stations and extension services. Under this arrangement, training, experiment stations, and extension services dealing with agriculture flourished. For engineering, only the training component was developed (Jones and others, 1990). The following example is a significant not only because of its success, but also because by virtue of its existence it is an exception.

In 1960, the Georgia Institute of Technology (Georgia Tech) established an Industrial Extension Division. After over 30 years of operation, it is not only among the oldest, but also most successful examples of industrial extension services in the U.S. A network of 12 regional offices around the state of Georgia are linked to a central office in Atlanta, which in turn, is the point of contact with the Georgia Tech Research Institute and Georgia Tech's engineering faculty. The extension agents, who have faculty appointments with the Research Institute, serve a wide range of industrial clients with a plethora of technical needs ranging from production line application to sophisticated computer-assisted design. Most projects undertaken by the extension service are short-term and "involve manufacturing processes, facility and materials planning, methods improvement, or cost control" (Jones and others, 1990, p. 14).

The service is designed for small, technologically unsophisticated firms that need assistance in achieving greater economic and competitive equity. The agents are assigned to geographic regions, and therefore generalists. When the request is more demanding in scope than a single agent can handle, researchers from the Research Institute are available if a particular expertise is required. Rarely do extension services offer research services (Jones and others, 1990).

The Industrial Extension Division is expensive, labor-intensive, and difficult to operate. Typically, two agents serve as many as 500 companies in a given region. The Division pays for up to five days of their time per project. Any additional time is paid by
the company in a contract negotiated with the agents. State support is low; agents and research staff must spend much time looking for and conducting contract research. In 1988, the entire extension system conducted $85 million worth of contract research and received only $3 million in state and other funding (Jones and others, 1990).

Georgia Tech's operation is the model for the Technology Consultancy Centre in Ghana, which Georgia Tech personnel helped to develop (discussed below) (Behrman and Fischer, 1990).

II.3. Science or Technology Parks

Developed countries have experimented with large industry-university collaborative arrangements called technoparks, science parks, or technology parks. Because of a wide variety of applications of these terms, science or technology park will refer to a project in which high-technology firms establish operations on a large parcel of land on, or adjacent to, a university or university-affiliated research institute for the sake of collaborating with the host institution, as well as with other participating firms. While the general concept has existed for several decades, it became especially popular during the 1980s.

II.3.1. U.S. - Research Triangle Park

Among the oldest science parks in developed countries is Research Triangle Park in North Carolina. Established in the late 1950s, the Park exists within a triangle formed by the University of North Carolina at Chapel Hill, North Carolina State University at Raleigh, and Duke University, in Durham. The Triangle region had been hard hit by the declining textile industry. Initiative for the Park came from the state's governor. From the start, the Park has had managed, rather than spontaneous, development. Initial development was slow, possibly because, unlike other early parks, it did not contain a premier research university. The Park began to make significant progress in 1965 as a result of the announcement by IBM of its intention to establish a major R&D facility at the Park. This led to the creation of 9,000 jobs and encouraged other large technology intensive firms to establish R&D operations at the Park. IBM's initial move amounted to a vote of confidence that was vital to the success of the Park (Monck and others, 1988).

This Park is different from other parks in the U.S. First, as mentioned above, the associated universities were not among the top ranks of research universities at the time that the Park began. Second, the physical climate is less attractive than that of other parks.
Third, the Park's development has always been managed. (Monck and others, 1988). Finally, initiative to establish it came from the state (OTA, 1984). The first three are noteworthy because they go against traditional thinking about the characteristics that are important for attracting companies to join a park. Nonetheless, there are two significant similarities with other parks. First, initiation of the parks and early support came from strong, determined individuals. Second, had the parks been evaluated too early, they might have been deemed failures (OTA, 1984).

II.4. Regional Development

II.4.1. United Kingdom - Industrial Orientation in a University

The University of Salford hosts one of England's most diversified programs of industry-university linkages. As with many of the other programs, it is designed to reverse regional economic decline brought on by a decaying industrial base. The immediate stimulus for creation of the program was a reduction in the University's public appropriation in excess of 40% starting in 1981 and spread over three years. The University's new Vice-Chancellor responded by developing a strategy designed not only to generate income but also to establish a distinctive niche for the institution in the UK higher education system. The history of the University's development has been documented by Segal Quince Wicksteed (1985 and 1988).

The objective was to develop a different type of institution that would have a strong industrial orientation. To achieve this objective, the University set up a variety of mechanisms to link the institution with industry. In the first five years, the University set in motion a wide-ranging plan that included:

- obtaining industrial sponsorship for four endowed chairs as in the German model;
- appointing industrial leaders to sit on the University's research committee so that industry would play an active role in determining the overall research direction;
- developing a new mechanism to promote the capabilities of the University around the world;
- developing a collaborative project with large firms nearby to provide education and training in information technology; and
- establishing a technology park next to the University.
Unlike other examples of technology parks, the one at Salford is not considered the focal point of the institution’s industry-university linkages. There are also applied research institutes with their own ties to industry, such as the Advanced Manufacturing Technology Centre, plus other mechanisms not mentioned above. This multi-faceted approach to linkages has several interesting organizational consequences. First, university administrators have direct oversight over all activities. They direct and influence, if not control, as much as they can. Second, the administrators want to know as much as possible about what individual faculty members are doing. The latter must register their outside work with the University authorities. Third, academics do not always comply with what some perceive to be unnecessary and burdensome bureaucratic requirements; they conduct their industry work "underground". At some institutions, as much as 50% of the collaborative work is done covertly. The control that makes this approach necessary likely discourages those who do not want to bother with registering their outside work but have no desire to resort to covert arrangements from collaborating altogether. In the long run, no gains from this, except possibly those trying to control the academics.

Another result of the desire of University officials to control what they can is that faculty members are no longer allowed to form their own companies. However, University officials have allowed at least one faculty member form a company as a division of the University’s industrial liaison company.

It remains to be seen if the control aspect restricts the effectiveness of the overall program so that it never reaches its potential. Time will also tell if a university that shifts so sharply toward an industrial, short-term perspective makes a significant sacrifice in not continuing to create new knowledge that industry will need in the future. A university that performs little or no research cannot support the kind of graduate program that produces the kind of graduates that industry wants and needs.

It is far too early to determine if the University is successful in reshaping itself to have an industrial orientation. Some of the services and programs may be more successful than others. Further, if the scheme succeeds, one consequence may be that the changes within the institution are so significant that the University ceases to be a university in the traditional sense.
II.4.2. U.S. - Experimental Program to Stimulate Cooperative Research

In some developed countries, the pattern of economic and technological development across a country has been uneven. Some regions become more advanced than others. There are a number of ways to identify the less developed regions, including share of national R&D support, research capacity of universities, production of baccalaureate and graduate degrees in science and engineering fields, and proportion of technology-intensive companies to other types of firms. No single indicator is perfect, but developing countries tend to be weak in a most or all of these areas.

Uneven development can create a perception of the country being divided into two camps -- the "haves" and the "have nots". This occurred in the US. The national government's response was to create the Experimental Program to Stimulate Competitive Research (EPSCoR). Established in 1980 by the National Science Foundation, the program has grown from five eligible states to eighteen plus the Commonwealth of Puerto Rico (NSF, 1990).

The program provides US$1.5 million per year to each state that qualifies for an award through a competitive process. Each award supports infrastructure improvement and research enhancement. The infrastructure component is intended to make permanent improvements in the state's research environment based on what is appropriate for the state. It includes human resource development through involvement in the research component and financial commitments from other sources that will become institutionalized at the end of the grant period. In this way, infrastructure improvement becomes self-sustaining (NSF, 1990).

The research component involves either group projects or the creation of a research center. While the program as a whole is geared toward bringing participating researchers up to a level where they are competitive for Federal research support, the centers also focus on involving students in research and creating linkages with other academic institutions, government laboratories, and industry. The linkages emphasize the exchange of personnel and facility access, as well as the provision of leveraging funds (NSF, 1990). Cooperating firms need not be located in awarded states.

The European Community (EC) Commission is currently studying the EPSCoR model in connection with the development of the EC's new STRIDE program for Less Developed Regions.
II.5. Newly Established Activities

II.5.1. Japan - Contract Research

For decades, Japan has focused on applied R&D. A higher proportion of Japan's R&D activities are privately supported than in other developed countries. Until recently, the country has not viewed basic research or industry-university relationships as important for its economic health. The government is presently changing its R&D priorities somewhat. More basic research is being supported and new initiatives provide incentives for private industry to support a greater portion of the country's R&D activities and, at the same time, promote industry-university collaboration (Rosenberg, 1990).

The Japanese government now allows universities to conduct research contracted by private industrial firms. The system also allows universities to employ industrial scientists and engineers on a contractual basis to conduct research. In 1988, the national universities earned 3 million yen from such contracts (Sigurdson and Anderson, 1991).

II.5.2. Japan - Centers for Cooperative Research

In 1987, the Ministry for Technology and Industry (MITI) established a series of centers for collaborative research between the national universities and private industry. Initially, three universities developed centers. Five more universities did so in 1988. More centers have been established since then (Sigurdson and Anderson, 1991).

Given the comparative newness of industry-university collaboration in Japan and the rise in importance of research institutes and research corporations, the role of the universities in Japanese S&T is unclear (Sigurdson and Anderson, 1991).

II.5.3. Contracting Out Industrial R&D to Universities

A global chemical and health care firm based in the Netherlands chose to "build" its own science capacity when the firm expanded to the U.S. by entering into a number of agreements with U.S. universities (Vleggar, 1991, p. 19). Collectively, these "clusters" of universities substitute for the traditional in-house corporate R&D program. Instead of employing its own researchers, the firm depends on faculty members, postdoctoral fellows, and graduate students to perform the necessary research. The firm views these arrangements as long-term, which is a benefit to all parties.
Three outcomes of these collaborations are particularly noteworthy for developing countries. First, "the relationships bring us into contact with excellent prospective employees." Second, the universities benefit not only from the firm's financial support of the research but also from patent income generated from patents developed in the projects (nine patents have been awarded in three years). Third, the firm believes that this type of industry-university collaboration "enriches the educational process for all involved" (Vleggar, 1991, p. 20).

After three years, the firm's U.S. operation has established 11 collaborative arrangements with US universities for work on 16 projects. Thus far, the firm has learned a number of lessons: (1) let universities have as much freedom as possible; (2) encourage a balance between the experience of faculty members and the enthusiasms of students; (3) monitor progress informally; and (4) use faculty members as consultants as necessary (Vleggar, 1991).

III. LESSONS LEARNED IN DEVELOPED COUNTRIES

Universities have more reason to collaborate with industry now than possibly ever before. In many developed countries, government support for higher education and academic research has been reduced over the last several years, and the trend is likely to continue. One obvious reaction is to look to industry to fill in the gap. In the process, structural obstacles, such as bans on industry paying academics for work, are being removed. One result of increased collaboration is that the universities are moving away from "ivory tower" remoteness toward more responsiveness to local economic needs (Bollag, 1990). In the process of turning to industry to solve financial problems, universities in Western Europe are starting to realize the possibilities of generating income from "commercialization of their specialist knowledge and facilities whether by means of publications, provision of continuing education, consultancy, contract research, licensing, new company formation, science park development or other activities" (Segal, 1987, p. 15).

Similarly, industry in developed countries cannot dismiss the increasing numbers of exceptionally successful collaborations. While industrial support for academic research is not, and has never been, high in any developed country, level of support is not an indicator of rate of collaboration or the value of a productive research relationship to companies.
It should be noted, however, that, for many years, there have been large incentives for professors in the U.S. and parts of Canada, who work for their universities on nine or ten month contracts, to develop collaborations. The additional months are available for conducting research, with the sponsor paying the researcher’s salary. While a faculty member is under contract during the academic year, he or she may have a research sponsor pay his or her institution for release time to conduct research instead of teaching a class. The final element of this arrangement is that faculty members are allowed to use one day a week for consulting. Unlike academic researchers in developing countries, these faculty members have had the freedom to collaborate and have not necessarily taken advantage of the situation.

III.1. Factors Promoting to Success

The single, most important factor in the success of any industry-university collaboration is the existence one person who initiates and nurtures the project. Such a person is energetic and views the success of the project as crucial for his or her professional development. Equally as important, beyond excellence in science, this individual has superb management capabilities. While there is certainly need for strong leadership, true collaboration can only occur if individual researchers make it happen. Formal agreements made by administrators are likely to fail (McHenry, 1990; NSB, 1982; Osborne, 1990; Van Dierdonck and others, 1990). Where there is little tradition of interaction, starting small, e.g., with individual research contracts, and then expand into larger collaborative mechanisms in time makes sense (Blais, 1990; Fairweather, 1990).

III.1.1. Building Partnerships

Starting small is also a good way of overcoming concerns stemming from uninformed perceptions. Academicians who have had little or no contact with industry assume that collaboration requires that they adapt what they do and how they do it to industry’s needs (Van Dierdonck and others, 1990). While companies need short-term applied R&D to solve problems, they can also profit from academic researchers serving as short-term consultants. Institutions and researchers geared toward basic research can provide benefit to companies by conducting long-term strategic research (Segal, 1987). Those in industry who have been successful promoting collaboration have found that the most fruitful ventures come about when the university participants do what they do best and are not force-fit into the industrial mold (McHenry, 1990; Vleggar, 1991).
In addition to those directly involved in relationships with industry, two institutional factors are significant. First, if the collaboration is to involve more than one-on-one relationships between university and industry personnel, the character of the university’s culture is important. Specifically, the question is whether the culture can be characterized as "entrepreneurial" (Segal, 1987, p. 18). In the absence of this feature, a strong leader, especially during periods of external financial pressure, can exert significance on the culture and direction of the institution. This was discussed earlier, but it applies as much in developing countries as in their developed counterparts.

One indicator of entrepreneurialism within university departments is the development of "spin-off" companies, or academic start-ups, in which faculty members start a company to commercialize an idea that has resulted from their research. The practice is clearly controversial and not always allowed. While there can be definite financial benefits for the researchers and economic benefit from the success of a new product, universities are concerned about the effect of the time spent working on commercial ventures on the quality of their teaching and their availability for graduate students. Some universities require that faculty members who establish their own firms give up their academic appointments (Etzkowitz and Peters, 1991).

The second institutional factor concerns the match between what universities can provide and what companies need. Proximity of partners, specifically clustering, were already discussed. In developed countries there are at least two schools of thought about the desirability of proximity in developed countries. Segal (1987) found that local linkages are convenient and frequently beneficial, but not always appropriate or sufficient. Stretching horizons may provide more intellectual stimulus for institutional growth that would not come about with a parochial partnership. There are undoubtedly circumstances under which this is true. However, Porter points to Rochester, New York, and Memphis, Tennessee, as examples where proximity of collaborators was responsible for the development of technology-based regional strengths (Morgan, 1992).

Academic researchers should be aware of the expectations of their industrial counterparts, as well as the role that collaborating companies believe that universities are best suited to play. In a study conducted jointly by the Government-University-Industry Research Roundtable of the U.S. National Academy of Sciences and the Industrial Research Institute (1991), senior research managers in a variety of companies had clear ideas about which party should be responsible for what in industry-university research relations. Specifically, they felt that it was a mistake for universities looking for revenue to reorient
their research toward project discovery, as they are not appropriately equipped to handle this role. Furthermore, the industrial researchers did not look favorably upon collaboration programs such as university-based research centers in which individual companies were affiliates of centers. "Generally industrial affiliates programs are not profitable...and generally, companies are less and less interested in participating. Those that continue to support such programs tend to do so either as good will gestures or to have access to students and faculty for recruitment" (p. 13). The industry research managers concluded that "the primary role for universities is as educator and provider of talent. This function is universities' greatest contribution to the process of innovation....Providing in-depth, fundamental understanding of scientifically and technologically new or emerging ideas is another significant role for universities" (p. 20).

The government's role is significant. Its most important contribution is to provide the stimulus for participants to identify each other and come together. The initial motivation is often government's willingness to provide at least partial support for a collaborative venture. Beyond the funding, government contributes to success by influencing the conditions under which the linkages take place. Thus, the governmental role is primarily that of a catalyst. University and industry partners actually make the collaboration come about (Blais, 1990; NSB, 1982; Osborne, 1990).

Porter argues that the national government, as distinct from local or regional governments, can be helpful in promoting the conditions under which clusters of universities and businesses form partnerships. Options include tax incentives for businesses that encourage private investment in growth firms, policies that encourage lively domestic competition, and expenditures for roads, airports, and training programs geared toward the needs of local industrial clusters (Morgan, 1992). In addition, tax credits for investing in industrial R&D and deductibility of new equipment donated to universities are viewed by many as significant stimulants for industry-university interactions (NSB, 1982).

The British Department of Trade and Industry (1987) developed a list of factors that contributed to the success of winners in the Industry Year 1986 competition. Experience has shown them to be important in other developed countries as well:

- combine the right people with the right structure. One without the other is insufficient;
- personalities matter. A driving force at the operational level is essential;
top-level commitment gives strategic clarity to the project and creates an environment in which successful collaboration can take place;

- collaborative projects need structural or facilitating mechanisms that give them freedom to evolve;
- the real benefits for collaborators derive from the process of collaboration;
- all involved need sustained motivation and commitment; and
- benefits accrue for both sides and knowledge is transferred in both directions.

It is possibly more difficult to identify unsuccessful collaborations than successful ventures. In fact, defining what is unsuccessful is murky. Some use the designation for collaborations that were intended but never took place. Others deem a collaboration unsuccessful if one party (usually industry) stops supporting the activity. The latter may be misleading. Industry can pull out for a variety of reasons, including deciding: (1) to develop the product another way; (2) that nothing will come of the project; and (3) that the work of academic colleagues is unsatisfactory (NSB, 1982).

III.1.2. Science or Technology Parks

While some countries have had several decades of experience with S&T parks and a number of them are at least a decade old, many were started in the 1980s (Blumenstyk, 1990; Finnish Academy of Technology, 1989; Van Dierdonck and others, 1990). Success, according to various definitions, is mixed. Belgium provides an example. Ten science parks have been started since 1972. Some of the older ones are fully occupied by firms. From this perspective, the parks are fairly successful. However, the extent of industry-university relationships presents a different picture. A study of collaboration showed that only nine percent of researchers working on industrial projects at universities housing science parks acknowledged any interaction with firms connected with the science park. Conversely, of the firms associated with the science park that participated in the study, more than half had R&D activities, but 32% had no link with any university. What interaction took place was usually informal. The vast majority of the firms with connections with the host university also had connections with other universities in Belgium, other European countries, and the U.S. (Van Dierdonck and others, 1990).

There are two principal formal means for establishing linkages in the science park context: academic start-ups and tapping in. Academic start-ups consist of firms created by faculty members who take their ideas out of the laboratory and start firms in the science park in order to move their ideas into the market place. Tapping-in involves firms without
experience with the host university joining the park in order to take advantage of the expertise, facilities, and knowledge available at the university. Both have been discussed previously. Van Dierdonck and others (1990) and Massey and others (1992) suggest that these approaches may not be especially effective if the goal is formal collaboration with the host university. In the case of academic start-ups, university regulations or meddling by administrators can hinder the creation of start-up firms (Etzkowitz and Peters, 1991; Segal Quince Wicksteed, 1988). The Belgian study and a similar one conducted in the UK suggest that the majority of firms in a park that could be tapping-in are not and, conversely, they may be more likely to tap-out, i.e., create collaborations with academics outside the park. Further, informal contacts may be far more numerous and significant between park firms and the host university than formal relationships (Van Dierdonck and others, 1990; and Massey and others, 1992).

Developed countries have learned that science or technology parks "require two or three decades to reach their full potential and involve millions of dollars of investment" (Lalkaka and Schiff, 1990, Annex II, p. 6). Unlike other mechanisms for building industry-university linkages, science or technology parks take much longer to take shape and develop full operational capacity. This fact is not always appreciated or heeded (Lalkaka and Schiff, 1990). As more of the university-based science parks run up against political and economic problems due to the time factor, park officials and proponents are rethinking their estimates of how much time is needed for the parks to work. In the U.S., early park failures have made many state and university officials aware of the need to reduce expectations, especially when seeking support from state legislatures, which are sensitive to political pressure for quick results (Blumenstyk, 1990).

The time element, plus the large expense, often lead to financial exigencies becoming the driver of operating decisions and changes in direction before enough time has elapsed for the original design of a park to be fully implemented. Under these circumstances, changes in operations or direction can alter the nature of industry-university linkages, leading to difficulty in evaluating their impact, efficacy, and outcomes (Lalkaka and Schiff, 1990).

Finally, effective linkages require active programs in place to bring about interaction between university researchers and science park tenants. Without such a mechanism, differences in orientation among tenants, researchers, and park managers will decrease the probability that interactions will occur on their own. Responsibility for bridging the gap
should be in the hands of one individual in the park management team (Lalkaka and Schiff, 1990).

IV. MODELS IN DEVELOPING COUNTRIES

IV.1. Small and Informal Arrangements

IV.1.1. Turkey - Revolving Funds

In 1981, Turkey's Higher Education Law established a mechanism that allowed universities to contract with industry to conduct research and perform consultancy work. Called Revolving Funds (RF), this source is one of four that support university R&D. A contract between a university and a client is simply a letter, but the university and faculty members involved sign a comprehensive contract in which the precise use of the funds is spelled out. Each university controls its own Revolving Fund, which is comprised of income earned from the industrial contracts. (Lalkaka, 1990).

The university's income, which can be as high as several million U.S. dollars a year, is split between researchers' salary supplements (40%), the University Research and Equipment Fund (35%), and university overhead (25%). According to the enabling legislation, the salary supplement may not exceed twice the total annual salary of the researcher. In reality, however, they amount to only about 80% of researchers' salaries; this is reached engineering departments of universities with large RF income. Researchers in other fields and those in the less prestigious institutions receive little or no salary benefit from their contract work (Lalkaka, 1990).

The program could work more effectively. First, even though two of the universities receive several million U.S. dollars in RF income, universities do little to sell their research services. Second, the same institutions receive most of their RF income from large state enterprises, such as waterworks, highways, and the armed forces, not the private sector. Third, not all faculty members who bring in RF income receive a salary supplement. Fourth, there are enough implementation problems -- most of which are due to the design of the program -- that it would make sense to consider modifications of original restrictions, incentives, and optimal size of the activity. For instance, most of the contracts have been for applied research; however, with salary supplements as the basic incentive for faculty researchers to participate, it is possible that routine test work, rather than true research, will
make up an increasing amount of the contracted activities. This is amounts to underutilization of the university researchers. Similarly, if RF growth continues at the present high rate, contract income may take the place of national investments to upgrade personnel capabilities and research facilities. The latter is needed to reverse brain drain (Lalkaka, 1990).

IV.1.2. Thailand - S&T Board

For a variety of reasons, industry-university relations in Thailand are mostly small in scale and informal. R&D expenditures are low compared with those of other NICs when their per capita income was comparable (Dahlman and Brimble, 1990). Similarly, it appears that the country's industrial sector "is not in the same league with Korea's, Taiwan's, and Singapore's at comparable points in their industrial development" (Westphal and others, 1990, p. 124). The lack of competitive pressure across firms, due to a protected and regulated industrial environment, has resulted in little private sector R&D activity. Further (Dahlman and Brimble, 1990):

- the industrial structure, which consists of many small firms (i.e., with 100 or less employees) and few large ones (i.e., 200 or more employees), makes technology diffusion difficult;
- while importing technologies remains the basic means of acquiring technology, traditional and new technologies are not utilized well; and
- most highly educated researchers work for the 16 public universities. Practical research is conducted, but not in any quantity and its general quality is questionable.

On an informal basis, consultancies between companies and university researchers take place and are probably the most common means of technology transfer in the country. Income supplements provided by the contracting firms encourage academic researchers, who are not paid well relative to their private sector colleagues, to collaborate. Arrangements are often made directly between researchers and firms and do not necessarily involve their university.

The main vehicle for public financing of R&D, the Science and Technology Development Board (STDB) program, has four components, two of which include direct industry-university linkages. Across the components, most of the awardees have been universities. The Competitive RD&E (Research Development and Engineering) component
supports research directed toward solving problems and is driven by industrial needs. Problem selection and proposal review processes include members of the private sector. Another component supports graduate training activities that foster public-private sector linkages for technology transfer through such activities as workshops and short courses (Dahlman and Brimble, 1990).

Closer linkages between the universities and industry are needed for more effective technology transfer. On a broader level, Thais need to be convinced of the importance of technology and investing in R&D (BioTechnology International, 1990; Dahlman and Brimble, 1990).

IV.2. Consultancy Centers

IV.2.1. Ghana - Technology Consultancy Centre

Ghana established the Technology Consultancy Centre (TCC) in 1971 to bring expertise from University of Technology, at Kumasi, to the productive sector, especially informal and small-scale enterprises. The objective is to promote Ghana's industrial development. TCC services are provided by faculty members from a number of Faculties, including Agriculture, Engineering, Science, and Social Sciences. Over the years, the Centre has been converted from a traditional extension service to one that emphasizes "the development, promotion, and transfer of appropriate technologies to small-scale industries" (Djangmah, 1992, p. 64). The Georgia Tech Extension Service, discussed previously, was the model for TCC, and Georgia Tech personnel assisted with the Centre's development (Behrman and Fischer, 1990).

At the time that TCC was established, there was great controversy over whether faculty members should be allowed to be paid for providing consulting services. Prior to reaching agreement on the permissibility of consultancy payments, 13 Engineering professors resigned in protest. Resolution came after the University sought advice from the Intermediate Technology Development Group in London (Djangmah, 1992).

Early on, small firms and individual craftsmen approached TCC for technical and general business assistance. Some were looking for information, others for manufacturing techniques. A number of enterprises sprang up as a result of the early inquiries. Initially, however, the Centre experienced difficulty transferring technology to entrepreneurs from the informal and small-scale sector until it developed the Intermediate Technology Transfer
Unit (ITTU). Established to assist clients who lacked the sophistication and education to work with formal institutions such as banks, ITTU provides a whole host of services, such as demonstration workshops of new manufacturing techniques, renting its own facilities or machinery to clients, and subcontracting entire or partial manufacturing orders to new entrepreneurs who are clients (Djangmah, 1992).

TCC provides services to large-scale firms and government agencies as well. These projects are usually larger in scale or require a greater level of technical expertise than those that are operated out of ITTU. Projects in which faculty members have consulted with large firms and government agencies have ranged in topic from road system design to developing new manufacturing techniques for brick, and have included the State Mining Corporation, an oil company, and the Ministry of Industries (Djangmah, 1992).

TCC is an autonomous unit in the University, and had the same director from 1972 to 1986. Both are important factors in the Centre’s longevity. While TCC is perceived to be a success both in Ghana and internationally, some believe that it has not lived up to the expectations that many University faculty members had for it. The specific concern is that the emphasis on appropriate technology and small-scale enterprise development diverts faculty members from part of the original function of receiving client inquiries and referring them to the appropriate University department. Faculty members feel that their real expertise is being underutilized, and that this reduces the effectiveness of the Centre (Djangmah, 1992).

IV.2.2. Mexico - Center for Technological Innovation

In 1985, the National Autonomous University of Mexico (UNAM) established the Center for Technological Innovation (CIT) within the Scientific Research Division. It was originally designed to provide services related to technology transfer. After three years of operation, half of the 125 projects had this focus, while 30 percent dealt with academic research and 20 percent with training. Nearly two-thirds of the projects emanated from within UNAM, compared with 37% from industry. The main explanation for the low proportion of industry-initiated projects is that, when CIT began, industry did not have a good understanding of the relationship between the need to innovate and market opportunities. As a result, CIT concentrated initially on working with academic researchers to transfer to industry technology in its earliest stages that they developed independent of market demand. For both academic and industrial clients, the Center provides a number of services, including (Waissbluth and others, 1988):
- conducting research that responds to industry's needs;
- identifying and contacting appropriate industrial clients with possible interest in a new technology;
- assisting communications between entrepreneurs and researchers on contracted projects at CIT; and
- consulting with other organizations regarding technology planning and selection and industrial research organization.

The Center is staffed with faculty members in engineering and the physical and social sciences. The University recognizes that their contributions depart from those of traditional academic faculty members. Criteria for the evaluation of staff working on CIT projects take into consideration that results of technology-based activities are frequently unsuitable for publication or appraisal by traditional academic means. Similarly, the University altered internal regulations to allow faculty members working on CIT projects to receive a portion of the income earned from the projects, such as royalties (Waissbluth and others, 1988).

The value of CIT goes beyond the services that it provides. The fact that the Center exists within a university sends a message to the rest of academia in Mexico that establishing ties with industry is a valid activity. The organizational arrangement makes a statement to those outside of UNAM, while broadening the faculty evaluation criteria demonstrates UNAM's commitment this change within the University (Waissbluth and others, 1988).

Despite UNAM's dedication to developing ties with industry through CIT, an unanswered question is the extent to which Latin American universities should assume the task of overcoming the deficiencies of industry by engaging in activities that have traditionally been outside the bounds of academia (Waissbluth and others, 1988). As was discussed previously, the University of Salford faces a similar dilemma in that its industrial collaborations are so extensive that the institution is moving away from being a university in the classical sense. The difference is one of balance. In broadening its focus beyond traditional academic research and publishing, UNAM is in a position to enhance its training of students by including them in CIT research projects and giving them contact with industry. In contrast, Salford has essentially substituted industrial collaboration for traditional academic research, thereby weakening its ability to provide graduate education. UNAM has a long way to go before CIT causes it to be in the same position as Salford.
IV.3. Science, Technology, or Industrial Parks

The science, technology, or industrial park idea has recently been introduced in developing countries as a mechanism to enhance technology commercialization and economic development by narrowing the gap between academic research and industry's need for technology. Being long-term projects and requiring the equivalent of several million U.S. dollars to operate, science or technology parks were practically nonexistent in developing countries until around 1990 (Lalkaka and Schiff, 1990).

IV.3.1. Taiwan - Hsinchu Science-Based Industrial Park

Like Thailand, Taiwan has few large companies. Small- and medium-sized enterprises (SMEs) have played a key role in the acceleration of Taiwanese economic growth. Since 1970, the number of employees per firm has dropped, while the number of firms has increased dramatically. With well over 100,000 firms, intense local competition has developed. The result has been the development of a wide variety of manufacturing industries. Unlike Thailand, most of Taiwan's R&D is performed by industry (public and private sector). In addition, most is either for development or applied research and concerned with engineering (Dahlman and Sananikone, 1990).

Coupled with this expansion of the manufacturing sector has been strong governmental emphasis on increasing the educational standard of the workforce. Rapid improvement in the quality of the workforce has enabled a transformation in the industrial structure from labor intensive to technology and capital intensive. All along, Taiwan has maintained and used effectively close linkages with the international economy. Like Japan and South Korea, it has developed policies that emphasize strategic industries, but not specifically through encouraging creation of large firms in the private sector (Dahlman and Sananikone, 1990).

The industrial restructuring is ongoing. Taiwan established the Hsinchu Science-Based Industrial Park (SBIP) in 1980. By 1989, the government had spent approximately US$320 million for land purchases, construction, and personnel. In addition to the Industrial Technology Research Institute (ITRI), two universities are key components of the Park: National Chiao Tung University, founded in 1896 and re-established in 1958 in Hsinchu, contains colleges of Engineering, Science, and Management. It also offers masters programs and several doctoral programs. The National Tsing Hua University was originally founded in 1909 and re-established in Hsinchu in 1957. It houses colleges of Science, Engineering, Nuclear Science, and Humanities and Social Sciences. Besides masters programs, a number
of doctoral programs are offered. Of the full-time professors, 92% have doctorates (Science Park Administration, 1989).

ITRI, a non-profit corporation, was established in 1973 "to act as a bridge between academic institutions and industries, [and] actively engage in the research and development of industrial technologies" (Science Park Administration, 1989, p. 4). This three-way interaction can occur in a number of ways (Science Park Association, 1989):

- technology transfer from ITRI to Park companies;
- training programs, e.g., on-the-job training programs and advanced degree study;
- private individual contracts;
- sharing and donation of facilities and equipment;
- seminars;
- intern opportunities for faculty during vacations;
- Park Administration innovation matching fund to encourage joint R&D projects between Park enterprises and universities; and
- easier and more frequent information exchange.

ITRI's role as a bridge, rather than a basic research institution, is different from other institutes in developing countries. Organizationally, it consists of seven laboratories dealing with chemistry (from materials to biotechnology), manufacturing (from machine tools to computer-aided design and computer-aided manufacture), electronics (software and hardware), energy and mining, materials, measurement standards, and electro-optics and peripherals. The Institute also provides information dissemination services for industry, which includes maintaining computer databases containing information on a variety of industrial technologies, publishing periodicals and books, and holding seminars to spread technical information (Dahlman and Sananikone, 1990).

A number of incentives to engage in R&D and training have been established in the Park. Several provide tax breaks: (1) R&D expenditures are deductible from taxable corporate income; (2) research equipment donations can be considered a deductible expenditure from corporate income tax; and (3) accelerated depreciation is allowed for R&D equipment. Other incentives include subsidized training programs, free seminars, and R&D duty-free importation of equipment for research in academic institutes (within the universities) (Science Park Association, 1989).
By 1989, 105 companies had been approved as participants, of which 98 were operating and 79 were making products. More than half of the approved companies were new start-ups, and most of the operating companies employed 100 or fewer workers. More than 16,000 people were employed by Park enterprises. Approximately 40% of them had baccalaureate degrees or above. As with Daeduk City in South Korea, SBIP attracts private firms and researchers from a variety of high technology fields: electronics, semiconductors, computers, telecommunications, precision instruments and machines, materials science, and biotechnology (Dahlman and Sananikone, 1990; Science Park Administration, 1989).

As with Korea, Taiwan has had a brain drain problem for a number of years. Approximately 7,000 students went overseas for advanced study in 1986, while, in the same year, 1,500 who had gone abroad previously returned home. Nonetheless, a number of recent events indicate that the problem may be becoming less serious. For many years, 90% of those graduating from overseas degree programs did not return to Taiwan. In recent years, the rate of graduates returning has doubled to 20% (Wu, 1992). Another factor is that the universities associated with SBIP are providing degree programs that are attracting students who could have gone abroad. In 1987 over 2,000 graduated (baccalaureate and above) from those institutions (Science Park Administration, 1989). Both new graduates and experienced researchers who were working abroad are returning to take advantage of the new technology-based opportunities provided by SBIP. Most have science or engineering postgraduate degrees from good US universities. In addition, those who return after working in the U.S. for extended periods have advanced skills in, for example, technology related to the information industry or with years of experience with highly successful firms in Silicon Valley (Dahlman and Sananikone, 1990).

Despite the significant role that industry-university collaboration is intended to play in SBIP, it was not evident in 1986 that the country as a whole was adopting the same approach. In that year, a quarter of all researchers (i.e., those other than technicians working in R&D in S&T fields with at least a baccalaureate) were employed in universities, yet only nine percent of R&D projects were conducted by universities. This is particularly noteworthy, since most university professors have PhDs from overseas universities. Either academic researchers are not performing much research and what they perform is basic -- only 11% of 1986 R&D expenditures were for basic research -- or the existing classification schemes are inappropriate (Dahlman and Sananikone, 1990). In other words, the way in which specific R&D projects are supposed to be categorized may not describe accurately what research was actually conducted. Similarly, the way in which expenditure data are derived may not have enough flexibility to capture collaborative research accurately.
IV.4. Newly Established Schemes

IV.4.1. Jordan - SME Vouchers for University R&D

Jordan has relatively high quality public universities. Unlike what is common in most industrialized countries, the universities perform most of the applied as well as basic research. In spite of the relative strength of the university research system, private sector R&D is not as highly developed. Protected markets and, in many industries, an oligarchic market structure, provide strong disincentives to innovate. Overall, there is a need for greater utilization of university R&D capability to address industrial research and training needs (Eisemon, 1991).

Jordan uses tax credits to stimulate industrial R&D expenditures and is considering instituting a revision of the tax code to increase R&D among technology-based firms in industries that provide much of the country's exports. These tax breaks would not be enough to stimulate SMEs (Small- and Medium-Sized Enterprises) with little or no R&D capability. To remedy the situation, a pilot test has been designed of a scheme to issue vouchers to SMEs for partial coverage of the costs of scientific, technical, and managerial services provided by the public sector. Firms receiving tax relief will be ineligible for vouchers. In the pilot test, only a few industries will be involved. In time, others will be added (Eisemon, 1991).

Vouchers can be used to purchase services from public institutions, including universities, and registered private firms. Each eligible firm would receive one voucher from the government for the purchase of approved services from contractors, who would redeem the vouchers at a designated bank or consortium of banks. One of the advantages of this system is its flexibility. It can be tailored to both the types of industries whose exports the government wishes to increase and the varying needs of SMEs at the same time.

IV.4.2. Romania - Consulting Centres for Private Initiative Development

Romania provides an example of how countries in Central and Eastern Europe are working to shed central government controls over the education and productive sectors. In 1991, the Polytechnical Institute of Bucharest and the Academy of Economic Studies in Bucharest teamed up with two U.S. universities to develop Romanian-American Consulting Centers for Private Initiative Development. The Centres are organized in a manner similar
to the U.S. Small Business Development Centers, which provide free and confidential consultative services to small enterprises requesting assistance (Sandu, 1992).

The Consulting Centre at the Polytechnical Institute of Bucharest has ranged from 12 to 16 clients since its establishment in October 1991. It is intended to provide technical assistance to small firms for between two and five years. Centre managers hold university professorships and are in a position to transfer technology developed at the university to the clients who are building small firms. In addition to this type of assistance, the Centre also provides business development, marketing, finance, accounting, and trade expertise. Overall, the Centre acts as a business incubator in that the association of client firms with the university is intended to reduce the risk of developing the business (Sandu, 1992).

Other Eastern and Central European republics are experimenting with different methods of collaborating. The experience of Slovenia is being documented by Kornhauser (1992).

IV.4.3. Korea - Interdisciplinary Research Centers

Korea established two types of interdisciplinary research centers in 1989: the Science Research Centers (SRCs) for advancement of new knowledge, and the Engineering Research Centers (ERCs) for development of new technology relevant to industrial applications. Funded by the Korea Science and Engineering Foundation (KOSEF), the SRCs are similar to the U.S. Science and Technology Centers. The ERCs resemble the U.S. Engineering Research Centers (discussed previously). In both Korean programs, funding for centers is awarded annually on a competitive basis. As a result of the 1989 and 1990 competitions, 14 SRCs and 16 ERCs had been awarded to universities across Korea. Each center receives approximately US$1 million per year (KOSEF, 1991; KOSEF, 1989).

The overall goal of the programs is that, collectively, the centers will be the future loci for innovation in Korea. During the development years, the centers are to increase in research quality and international visibility; disseminate information via seminars, workshops, intensive training, and publications; and provide continuing education for and collaborate with staff in industry and government research institutes (KOSEF, 1991). The main difference between the programs is that SRCs focus on pure research, while ERC research must have industrial application (Kyung, 1992).
While research is the primary focus in both programs, education is a close second. The centers are intended to provide excellent preparation for students who, in 10 years, will lead Korea's development. Graduate students and postdoctoral fellows are already involved, and undergraduates will be included in the future. In order to improve the quality of research and professors at the centers, KOSEF intends to entice more and more of the Korean students who previously would have studied abroad to study at universities with SRCs and ERCs instead. Program designers also intend for the centers to play a significant role in reversing Korea's earlier brain-drain problem by conducting research that is sufficiently interesting to convince researchers who stayed abroad after schooling to return home (Kyung, 1992).

These programs are noteworthy. While in their design they are similar to programs supported by the U.S. equivalent of KOSEF, they are tailored to meet the needs of Korea. In many ways, they are quite different from the U.S. models. The SRCs and ERCs are clearly elements of a national strategy for strengthening research, education, and technology development capabilities. Goals are clear and incentives for participation are built into the designs of the programs.

IV.A.4. Turkey - Technoparks

During the 1980s, Turkey experienced improvement in industrial production, foreign investment, and export volume because of its market-oriented development strategy and favorable international circumstances. However, industrial enterprises continued to use 1960s and 1970s technological processes. Most research takes place in universities; what is officially termed R&D activity in universities is actually test work or problem-solving. The private sector supports at most 10% of the R&D activity and a growing proportion of public funds support defense-related projects. Overall, R&D activities are weak compared with those in the NICs. For example, while Korea has a per capita income of three times that of Turkey, its R&D expenditures are nearly 30 times that of Turkey (Lalkaka, 1990).

To catapult its technological development into the 1990s, Turkey seeks to develop strength in information technology. As a part of that goal, it began establishing five technoparks in 1991. There are a number of reasons for doing so at this point in the country's development. First, Turkey is proficient in technology adaptation. This capability has been the primary component of technological development efforts. Second, the country has industrialists and entrepreneurs, and the government has established programs to promote the creation of new technology-based firms. Third, there are some technical
universities and scientific institutions that conduct basic and applied research (Oppenheim, 1992). Finally, the economic progress of the 1980s caused industry and universities to begin recognizing their respective strengths. Initial interactions have paved the way for the technoparks (Lalkaka, 1990).

Collectively, the five parks have three functions: (1) as business incubators for small technology oriented companies; (2) as a channel for commercializing technical know-how developed at the universities; and (3) as attractive sites for the in-house R&D operations of larger corporations (Oppenheim, 1992). With few R&D operations in large companies, and a mismatch between the types of research that universities produce and what industry needs, the technoparks will need to provide many services to bring both sides together and fill in skill gaps (Lalkaka, 1990). Among other things, the technoparks will need to provide training in technological entrepreneurship, marketing, and finance. They are also expected to provide the means for entrepreneurs to take advantage of university facilities, such as libraries and computers (Üçcan, 1990).

At the outset, there was great interest in the technoparks by chambers of commerce and industry. Each park has a different assortment of participants. At initial registration of participants, one had 89 partners, while another had received 50% of its funds from the private sector and 50% from the collaborating university. Lalkaka (1990, p. 12) found initial progress to be good and forecasted that "if university-business enthusiasms (and SPO [State Planning Organization] support) can be sustained for the next two or three years, a few incubators and parks could come into operation, each with 10-15 start-up enterprises in technology-related products, research and services. These tenant companies would be good candidates for collaborative research with their sponsoring universities, for FWT [Fund for World-class Technology]."

From the beginning, the technoparks have faced a number of problems. The top technical institutions produce graduates who could form a class of technology entrepreneurs, but many leave the country for better opportunities. Links between industry and universities have been weak because R&D activities have generally been unresponsive to market forces (Oppenheim, 1992). In addition, as late as 1990, government regulations impeded interaction. University researchers were not allowed to work for industry. Those who developed skills in specialized fields outside of academia could not pursue PhD studies. Further, structural factors within universities had a negative effect. Masters and PhD programs were generally not geared to meet the country's needs, so courses of study did not relate to practical application and graduates were not equipped to solve industry's problems.
Finally, teaching is the main function of professors, who course loads are so large that they have little time to conduct research (Üçcan, 1990).

V. LESSONS LEARNED IN DEVELOPING COUNTRIES

It is useful to approach the dissemination of lessons learned as a form of knowledge transfer. There are important similarities among developing countries — independent of region — that make lessons learned in one region worthy of attention in another. Focusing on differences is a mistake. Yet, while no country or region has a corner on the development market, so to speak, no model is completely transferrable from one country or region to another (Ranis, 1990).

V.1. Necessary Conditions for Collaboration

In 1989, Decio de Zagottis, Minister for Science and Technology in Brazil delivered a speech before the Tenth Session of the Intergovernmental Committee for Science and Technology for Development in which he listed the items that he believed are necessary to facilitate industry-university interaction in Brazil. While his list and focusses on one country, Brazil, many of the items apply to other developing countries as well:

- Universities need to obtain information about industry's existing, potential, and future technological demands;
- Universities, and especially engineering schools, must create a feedback mechanism with industry to enable academia to keep track of existing knowledge in industry;
- Industry must pay adequately for consulting services provided by university researchers; and
- Interaction should focus on preparing and updating the skills of R&D personnel, acquiring and generating technology, and technology transfer.

A number of studies support pieces of de Zagottis's observations. In one dealing with building science capacity in nine developing countries, Behrman and Fischer (1980) concluded that the traditional triangle model of what is necessary to build science infrastructure lacked a number of factors. To the triangle consisting of government, industry, and universities and research institutes they added three components: (1) "a
science community oriented to industrial research coming out of the three previously mentioned groups; (2) a body of industrial users, who apply the technology; and (3) "a market that elicits and utilizes S&T results, making the effort profitable" (p. 101; all emphases in original text).

The key to this system functioning properly is that strong linkages exist among all six components. Across the countries they studied, the principal gap that Behrman and Fischer (1980) found is the lack of market pull. Specifically, they noted that there was insufficient competition among local firms in all countries studied, which resulted in little desire to upgrade technology. This was due largely to an inadequate appreciation by industry of the role of technical innovation, as available technology seemed to fill existing needs. Nonetheless, a weak market signal often conflicted with governmental programs requiring local R&D activities. In many countries, this was exacerbated by a lack of trust of the industrial sector in the ability of academic researchers.

Many have examined what is necessary in order for science and technology to become the means for economic development. Like Behrman and Fischer (1980), Freeman (1989) identifies the need to develop a national system of innovation, rather than specific products. Freeman's approach has more components and appears more complex and advanced than Behrman and Fischer's. While Behrman and Fischer focus on linkages between components, Freeman emphasizes development of the components themselves -- universities, research institutions, technological infrastructure, industrial training systems, information systems, design centres, and other scientific and technical institutions -- as the building blocks for S&T-based economic development (p. 97). It may be that the two views are appropriate for different stages of development.

V.2. Factors Contributing to Success

Calibrating success is a difficult, and sometimes risky, endeavor. Identifying factors contributing to success can be even more challenging. Standard evaluation methodology links programmatic goals and objectives with outcomes and impacts which in practice may or may not be measurable. There are those who believe that the most important goals defy quantification.

Starting from the position that the simplest approach is often the best, success in the context of this paper is defined as the development of linkages between universities and
firms that: (1) are beneficial to the individuals directly involved and, more generally, to their organizations; and (2) contribute to the country's economic development.

Several have studied the background characteristics that make successful industry-university relations possible. Ranis (1990) examined the South East Asian NICs to determine factors that have contributed to their progress. One factor was how researchers chose projects. Taking as his example the S&T institute, common in developing countries, he found that successful South East Asian countries and Japan (shortened to EAJs) "force such institutes to be useful to the market place either by only providing a partial subsidy and/or one that is being reduced over time, as was the case with the Korea Advanced Institute of Science and Technology (KAIST), or by policies designed to encourage firm level R&D through tax provisions that permit the current costing of R&D" (p. 172). In other, and less successful, developing countries, the government tended to be the main financiers of institutes, whose researchers were motivated more by the directions of "hot" research topics in international academic circles than by translating technologies for market use. Ranis concludes that the EAJ emphasis on private sector contracts rather than governmental subsidies played a large role in the choice of research projects. Choice may be affected not only by the source of funding but also by the terms of the financial agreement.

South Korea has several examples of how a government can stimulate development of research capacity and the economy simultaneously. KAIST (reorganized in 1989) is notable not only for incentives to work in areas that have applications in the market place but also for combining graduate training, research tied to economic needs, and measurement and standards development in the same institution. The two new centers programs, SRC and ERC, illustrate a similar approach to combining incentives with an organizational framework that also focus on doing several things simultaneously in one institution. One of the key features underlying the centers programs and KAIST is that no component is intended to function independently of the others. It is not surprising, therefore, that a notable number of SRCs and ERCs were awarded to KAIST.

Support for S&T activities, be they performed in universities or industry, should be focussed on the country's or region's highest priority areas (Freeman, 1989; Muskin, 1992). Identifying and occupying a niche that reflects local conditions, resources, and comparative advantages should be the goal (Freeman, 1989). Porter points to Japan as an example of a country that also recognized the role of disadvantage in determining priorities and spurring innovation (Morgan, 1992). Identifying and compensating for disadvantages makes it
possible to put comparative advantages in better perspective. This approach is probably as valid for universities and individual companies as it is for countries.

V.2.1. Incentives

In most developing countries, at least in the earlier stages of development, industries conduct little if any R&D. This is a major barrier to fruitful industry-university relations. Moving beyond this situation may involve interim steps, such as firms contracting with universities for R&D assistance. However, if market signals are weak, positive experiences with this type of small-scale collaboration may not provide enough stimulus for firms to begin developing their own R&D capability. In the case of Thailand, removing government controls over the industrial environment is necessary before competition can develop in the private sector and the role of technological improvement becomes evident to individual firms.

Unlike some developing countries, a number of Central and Eastern European countries have had the necessary human resources for expanding S&T capacity, but the lack of market competition with its incentives for improving products and production methods kept those with research training from working on projects with industrial application. These countries were not involved in the technological innovations that characterized the 1980s and provided a vehicle for a number of East Asian countries to become NICs (Thulstrup, 1992).

In a review of Bank lending for science and technology, Muskin (1992) identified a number of incentive strategies that encourage researchers to collaborate. Generally, they seek to optimize their own advantage. Operating from the premise that inefficiency results when people are given additional resources without having to justify need or undergo evaluation of previous productivity, strategies such as competitive bids or competitively reviewed proposals for additional funds produce more desirable results. When third parties provide support on a competitive basis for collaborative projects, it is useful if the review process includes members of all parties. In this way, everyone shares responsibility for the decisions and has a stake in the success of the selected projects.

Resources can be used in other ways to encourage collaboration. One method is to couple the immediate benefits to individuals with benefits to the institutions with which they are affiliated. Along these lines, Muskin (1992) advocates increased reliance on industry contracting with university for such things as access to instrumentation, facilities, testing, or
consultative services. Companies would buy what they need and universities would receive income from fees charged for services rendered. Individuals supplying consulting services would also receive remuneration. Fee income received by the universities would encourage similar ventures in the future. This type of incentive system not only increases efficiency, but also builds the linkages between sectors that are necessary to build the overall infrastructure. It should also strengthen demand for research.

In practice, it appears that setting a limit for the income that academic researchers can earn through contracting does not guarantee that they actually receive much remuneration. In the case of Turkey's Revolving Funds, participating faculty members have not received nearly as much income from their involvement with industry as the program allows. In countries where faculty salaries are low compared with those in industry or other countries, inadequate reimbursement of faculty researchers for services rendered to industry may not only discourage individual collaborations but contribute to brain drain that may already be a problem.

The Revolving Funds experience suggests another lesson. The program was intended to support research, but a significant proportion of contracted work has been for pilot testing. As long as the program allows this to continue, firms will have no incentive to establish their own testing facilities, and no one will be inclined to collaborate on true research projects.

V.2.2. Structural Factors

Proximity of university laboratories and industry is critical if collaboration is to take place (Nelson, 1990). Close proximity encourages personal contact, personnel exchanges, equipment gifts, and sharing of facilities (NSB, 1982). According to Porter (in Morgan, 1992), it also leads to the development of entire systems, or clusters of collaborators. These industrial clusters include universities that create specialized programs, research institutes that are established to meet certain needs, specialized infrastructure, and suppliers who become interested in being involved.

Ease of access of partners to each others' facilities is the essence of many collaboration models. With long distance transportation and communications being difficult in many developing countries, collaborative ties are easiest to arrange if the partners are near each other. This is particularly true when collaboration includes students working at industrial facilities. Proximity is also likely to be important for the success of science or
technology parks. Similarly, proximity may also encourage firms near science parks to become partners. One technopark in Turkey located in an area with a strong industrial base had 89 sponsors at the outset, most of which were industrial firms nearby.

All successful developing countries have made major investments in education and the strengthening of S&T capabilities. These investments are not often easily afforded because of the relative poverty of the countries at the time that the investments are made. Nonetheless, providing research support for university faculty that enables them to stay current with their fields "is probably the most important thing a government can do to push along the industrialization process these days" (Nelson, 1990, p. 79-80).

This support also provides a crucial vehicle for developing degree programs to educate undergraduate and graduate students at home. Brain drain is a serious problem in many countries that have traditionally sent students abroad for science training. By building university research capacity and improving pre-college science education, countries develop the means to offer their own undergraduate and graduate programs. In addition, building industrial R&D capacity and collaboration with universities provide employment opportunities at home for those who stayed abroad after obtaining foreign degrees.

Collaboration can also expand employment opportunities at home for S&T graduates. Those who become involved in industry-university research as students become familiar with the needs of a particular industrial sector, and learn about industrial careers. In some countries where S&T graduates would traditionally go to work in the public sector, there are no longer adequate job opportunities. Experience in industry prior to graduation can motivate graduates to consider private sector opportunities. Such a shift in employment sector can benefit industry, as firms want universities to provide them with good graduates.

Building the research capacity of university researchers and their ties to the international science community provides another benefit for industrial participation in collaboration. Countries with weak or negligible industrial R&D activities need means to upgrade the skills and knowledge of industrial personnel. This study concentrates on the benefits of universities providing training for industry personnel in the context of research centers or science parks. Nonetheless, the same approach can be effective in building the functional capacity of firms through technological advancement when firms need more fundamental assistance. Industrial extension services are a good example.
Overall, one of the most frequent problems experienced with the models discussed in this paper is the frequent mismatch between university and industry researchers' skills and substantive orientations. The differences in orientation have been described earlier. However, differences in skills and knowledge level have often been a problem impairing the effectiveness of some of the models. Across the countries and models examined, no party is consistently stronger than the other. In some countries the universities surpass industry, but in others industry is superior and does not trust the quality of the work performed in universities.

Industrial firms also often take a dim view of working with university researchers who only conduct basic research simply because it is "better" and more prestigious, even though it has no direct relation to economic or industrial needs. This has been a problem in some of the most scientifically active countries in Latin America. It is not a new problem. Behrman and Fischer (1980) concluded from a 1979 study of nine developing countries that "developing local capabilities for the generation of technology obviously should be directed toward the goals of development, unless the objective of science is merely to assuage the curiosity of scientists (emphasis in original text)" (p. 103).

Muskin (1992) notes that within higher education, the existence of private institutions may be important for the advancement of S&T, although they tend to be limited to some natural science fields because of cost. However, having a specific focus may be advantageous for universities, as it is for research centers and institutes. He points to the development of the sub-sector as a component of a larger effort to develop a private sector. There is precedent for this view. In the United States, there is a distinct relationship between the number of private research universities in a state and the state's annual academic R&D expenditures. Taken collectively, the ten states that have the highest expenditures have roughly the same number of public as private research universities. In contrast, the 17 states with the lowest academic R&D expenditures have a total of two private institutions (Burton, 1990). Private universities receive a large proportion of their support from private philanthropies and industry and were generally founded by individual entrepreneurs who played significant roles in the industrial revolution during the Nineteenth Century. States with little industry are unlikely to have developed private universities.

De Zagottis (1989) identified a number of elements that are important for successful collaboration in Brazil. More generally, the list summaries lessons learned in other countries regarding elements that relate to success:
• involvement of masters and doctoral students;
• continuing education conducted by universities to train and update industry professionals;
• university capability to respond rapidly to industry needs and manage joint projects competently;
• industry mechanisms that encourage interaction; and
• freedom for academic researchers to perform both technological research as well as more traditional academic research with direct industrial applications.

V.2.3. Planning and Implementation

Lackluster success, as well as actual failures, can be the result of poor or incomplete implementation of a plan. Personnel, government, and policy changes during any stage of a project can affect implementation. A program can be implemented differently from the way in which it was envisioned during the planning stage. An example is Turkey’s Revolving Funds program. The legislation establishing the program allows participating faculty researchers to receive a significant stipend. As mentioned previously, only engineering faculty members receive close to the remuneration for which they are eligible. Thus, the way in which the program was implemented failed to create incentives to participation for some who are eligible.

Lack of appropriate skills or foresight can also impair project progress. Complex collaborative arrangements, such as research centers and science parks, can be less than successful if equipment is allowed to deteriorate beyond repair or maintenance. Lack of trained technical expertise is usually the biggest problem. While providing technician training should be a part of the job of university research centers and science or technology parks, it may not come about. Companies wishing to upgrade their production standards may be unable to do so because they lack technicians with the skills necessary to implement any upgrade (Behrman and Fischer, 1980). Thus if the facility, be it a research center or science park, has an objective of improving production standards via a formal program, the entire activity can be sidelined if another component program, e.g., technical training, is not implemented as planned. The more complex the overall effort, the more success depends on the timely and successful implementation of each part.

Finally, establishing good working relations is not enough for success. People may be able to work together without being productive. Conditions may be good for collaboration, but no tangible results may appear from the activity. The missing component is
entrepreneurism. At least one member of a partnership must have entrepreneurial skills. Building a technology-based economy involves awareness of markets and what niches competitors are pursuing, be they in the same region, or globally. To the extent that industry-university R&D collaborations are intended to contribute to economic development, collaborations must focus on what is useful for participating firms. Figuring out what is useful and how to create innovation as a result of collaborations involves entrepreneurship. Planning, developing strategies, determining comparative advantages and disadvantages, identifying opportunities, taking intellectual risks, and convincing potential partners of the advantages of entering into collaboration are all part of entrepreneurship. Knowledge of the importance and role of these factors is often weak.

VI. READINESS FOR COLLABORATION

An underlying assumption in any discussion of industry-university relations is that both parties are ready for such interaction. Both need to have achieved a certain amount of performance capability in order for there to be a basis for collaboration. A university with research facilities and faculty trained in Western universities can do little for firms that have no technological orientation and are unable or unwilling to adopt more sophisticated techniques. Conversely, firms that seek to move from importing technology to producing it themselves have little to gain from relations with universities that have poor research facilities and no faculty members with the necessary research skills. At the most basic level, universities need to have something to offer industry and industry needs to be in a position to benefit from university assistance.

Many collaborations that might have been successful only last a short time or never reach their potential. One common reason is that not all the necessary linkages were made to translate the result of the collaboration into application. It is not enough for those directly involved to have a productive relationship. If the industrial partner is not able to move the results of the collaboration into use, the firm may be no better off than it was before the collaboration. There would be a gain, however, if the industrial partner acquired skills or knowledge in the process of working with academic colleagues. If the new knowledge or skills are put to use, the collaboration would be a partial success. Seen as discrete, unconnected activities, collaborations cannot produce significant payoffs within an industry or for the economy. They must be a part of larger efforts to meet industrial and economic needs.
Another reason that some collaborations seem to go nowhere is inadequate support for the activities over time. Waffling support is a sign that initial commitment may not have been especially strong. If the activities are not valued by the participating universities and industries, incentive systems may be changed to make them less attractive for researchers to participate. Similarly, a short-term view on the part of those paying for the collaboration can lead to support being reduced or eliminated if results are not produced in a limited amount of time. Large government-sponsored projects can meet their demise if political (and therefore financial) support is not dependable. A good example is the saga of a number of U.S. science parks, for which state support was not nearly as stable as anticipated at the outset. To minimize the possibility of failure, large, expensive collaborative ventures should, from the beginning, be viewed as high political and financial priorities by all involved and commitments for long-term support should be firm. In the absence of these conditions, such ventures are risky and suggest that the partners are not entirely ready to undertake a large, complex activity (Blumenstyk, 1990).

VI.1. Stages of Development

There is no definitive means of determining readiness. One approach uses the stage of science and technology development of a country or a region as a crude approximation of functional capability and institutional capacity. It is considered by many as a useful guide for assessing the strength of a country's or region's higher education system and private sector when determining how to build R&D capacity in general and technological capacity in particular. It is equally appropriate for assessing the potential for industry-university collaboration.

The same considerations that go into determining stage of development for the purposes of gauging technological capacity apply when assessing readiness for industry-university relationships. Substantial literature exists that describe systems for codifying countries (c.f., Eisonman and Davis, 1992; Kamenetzky and others, 1986; Stewart, 1990). Some are linear and assume that, as countries develop economically, they become more industrialized and technologically sophisticated (Kamenetzky and others, 1986; Stewart, 1990). Others, such as that described by Eisemon and Davis, focus on the nonlinear clustering of historical, economic, ideological, and political circumstances that surround different types of national research systems. Neither approach assumes that there is a single developmental sequence for all countries.
Codification systems, especially linear ones, are viewed by some as destructive when they are used to establish eligibility or ineligibility for restricted activities. In some cases, such as the EPSCoR program in the U.S., eligibility marks the state, country, or region as inferior. When using stages of development to gauge readiness, it is important that decisions do not become formulaic. While it may be tempting to assume that if a country belongs to stage X, it is capable of Y types of activities, this is a misuse of codification systems.

In the final analysis, systems that gauge stages of development are most useful in helping identify the range of industry-university collaborative activities, if any, that a country might be ready to pursue successfully. It is a way to begin evaluating needs, opportunities, and capabilities.

VI.2. Indicators of Readiness

Beyond stages of development, readiness can also be examined with the use of more specific indicators of readiness. This is a more detailed method, but it is still full of caveats regarding how to interpret the results. Using indicators is probably most useful after considering a country's stage of development.

Collectively, indicators have the advantage of the nonlinear codification system in that they allow consideration of such circumstances as the country's or region's history, economics, ideology, and politics, which affect the likelihood of success. This list is far from complete, but provides an idea of what factors are worth considering. Additionally, the weighting of importance of each indicator must be country-specific and not all indicators are appropriate for every country. Some indicators require judgement, others are numeric.

Neither gross R&D expenditures nor the number of research scientists and engineers is included. First, these statistics are generally not available for developing countries, at least as compiled by the Organization for European Cooperation and Development (OECD) for industrialized countries. Second, if they exist, the accuracy is doubtful (Coward, 1990). The less developed the country, the more likely it is not to collect the kind of R&D data that are used as indicators of R&D capacity and productivity in developed countries.
VI.2.1. General Indicators

Decentralized higher education and R&D systems indicate that individual institutions have control over their resources and priorities. Decentralized organizations tend to be more responsive to local or regional needs.

A well-educated workforce is capable of developing and implementing technological innovation. It is also capable of solving problems and identifying new opportunities.

A. Higher Education Indicators

A significant history of higher education suggests that higher education has been valued by some segment of the population over time. Without investigating how it has fit into the society, it is not possible to determine how important it has been and to whom.

A private higher education sector indicates private sector support of higher education. In a few cases, research capacity in private universities surpasses that in public institutions.

One way of gauging the quality of a higher education system is the extent of university researcher contact with the international science community. Contact with the international community indicates exposure to a continuous flow of new knowledge for both faculty members and graduate students. It can include attending international meetings and publishing in internationally recognized journals. Publications are often used as an index of the research quality and productivity of a department, institution, or country, but they should not be used as an indicator of S&T development. They can overstate overall S&T capacity when university researchers publish to meet institutional expectations but industry is operating on a much lower technological level, as in some Latin American countries; conversely, publications understate overall S&T capacity in countries where, as with the NICs and Japan, less emphasis is placed on basic research for general advancement of knowledge than on building industrial capacity. As de Zagottis (1989) explained, universities should have the freedom to perform both technological research as well as more traditional academic research with direct industrial applications. "The latter must of necessity respect social priorities, and not necessarily be compatible with needs or bibliographical contexts from fully developed industrial societies" (p. 12).
VI.2.2. Industry Indicators

A significant amount of technology-based industry signals the existence of firms that appreciate the need to upgrade the technology of their processes and products. This type of industry becomes more competitive as it moves from importing technology to developing its own indigenous technology. Since few industries of this type have significant in-house R&D capabilities, they are well suited for collaboration with universities.

Progress toward developing indigenous technology and less reliance on imported technology are good clues that a country is not only interested in building its technological capacity for industrial use but also in building the capacity of its higher education system to produce the highly trained personnel needed to achieve the conversion and to provide research services.

Some level of market pull is important if there is to be benefit from collaboration. A number of countries that are otherwise good candidates for successful industry-university relationships (e.g., India and Eastern Europe) have controlled economies with little or no market forces. Lack of competition among firms provides no incentive for applying the results of a university collaboration to production. The absence of market signals negates any benefit from technological advantage. Countries in the process of reducing economic control may or may not develop competitive commerce by themselves. History, tradition, and culture are important determinants of the need for external stimulus to create competitive markets.

VI.2.3. R&D Capacity Indicators

The distribution of R&D expenditures by field often reflects a combination of natural strengths, prior policy decisions, and current positions. In a developing country that has extensive mineral reserves, one would expect a significant proportion of R&D support to continue going into mineral extraction and raw material conversion research. However, expenditures should also show the extent to which the government is trying to expand the economic base beyond minerals, both in terms of building other industries and increasing the technological sophistication of the mineral industry. Expenditures are not a good indicator of the quality of research capacity (Thulstrup, 1992), but they give a signal about government priorities.
The distribution R&D expenditures by performer provides information on the share of government expenditures received by each R&D performer. In some countries, nearly all support goes to universities, while in others industry receives a significant share. This indicator shows the balance of government expenditures, but does not include spending by industry on its own R&D facilities or university spending to support in-house research. It usually does not include indirect support for such things as tax incentives for equipment donation.

Occasionally, university R&D expenditures by source is used to examine the degree of diversification of research support. It is useful up to a point to see what progress countries are making if they try to decrease government support of university R&D relative to that of other sources. Data used for this indicator can be misleading. Table 1 illustrates why technically correct numbers can mask actual expenditure sources and limit the utility of this indicator.

Table 1: University R&D Expenditures by Source

<table>
<thead>
<tr>
<th>Country</th>
<th>Industry</th>
<th>Government</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>1%</td>
<td>98%</td>
<td>1%</td>
</tr>
<tr>
<td>Japan</td>
<td>2%</td>
<td>51%</td>
<td>47%</td>
</tr>
<tr>
<td>UK</td>
<td>7%</td>
<td>74%</td>
<td>19%</td>
</tr>
<tr>
<td>US</td>
<td>7%</td>
<td>86%*</td>
<td>7%</td>
</tr>
</tbody>
</table>

* Approximately 60% from Federal Government, 26% from state and local governments

Source: Science Resources Division, NSF

Without further breakdowns, the Government and Other categories are actually distorted. The 47% Other for Japan contains mostly university funds, which come from the government. Thus government funds are passed to universities and then reallocated to in-house academic R&D activities. The table does not reflect the pass-through, so Japan appears to have far more diversified support for its academic research system than it really does. Similarly, Government support can be understated when the value of tax incentives is not included.
The ratio of R&D expenditures to GNP is frequently cited by those looking for quantitative means to assess R&D capacity. While widely used, it provides useful information only under certain conditions. In general, it does not reflect the R&D output, only the input. This is a serious flaw, because research efficiency varies greatly among institutions and countries. It is generally assumed that the higher the ratio (i.e., surpassing 1%), the more likely the country is to have a level of R&D capacity that could benefit from industry-university collaboration. The lower the ratio, the less it means and should be considered. But even when compared over time, this ratio does not reflect increases in R&D expenditures well, particularly if the initial amount is extremely small (Eisemon and Davis, 1992). Finally, it should not be used as an index of the quantity or quality of a country’s graduate S&T education. Countries with relatively high ratios, e.g., Japan, Taiwan, and Korea, still educate many of their graduate students abroad (Thulstrup, 1992).

The stability of R&D funding is a useful gauge of the ability of a system to sustain if not expand its R&D capacity. In general, instability suggests that R&D capacity may erode over time. It frequently accompanies long spells of economic or political instability. Insufficient support can contribute to a variety of problems, including brain drain.

VII. FINAL COMMENTS

There are many reasons for developing countries that are ready for industry-university relationships to develop them. This paper has discussed a variety of means currently in use around the World and ways of determining what options are appropriate under different circumstances. It does not present a cookbook approach to thinking establishing collaborative relationships. Unfortunately, some approaches have not been included because an insufficient amount of information was available.

From examination of what has been done and which lessons have been learned, several conclusions emerge. First, industry-university collaboration is most likely to be successful if a variety of interconnected elements are present, such as faculty members trained in conducting research, appropriate research facilities, incentives for faculty members to work with industry, and enough market pull to provide incentives for industry to desire collaboration. Second, success in industry-university collaboration involves adoption of at least some of the values and norms associated with Western universities. Finally, the existence of industry-university collaboration may actually be more important as a symbol of the importance of doing work that relates to economic needs than the actual mechanism used or the utility of the research results.
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