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The Philippine Innovation System: Structure and Characteristics

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PHILIPPINE INSTITUTE FOR DEVELOPMENT STUDIES
Surian sa mga Pag-aaral Pangkaunlaran ng Pilipinas

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List of Abbreviations

ASTI	Advanced Science and Technology Institute
BOI	Board of Investments
BPS	Bureau of Product Standards
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CAPE	Consultancy in Agriculture for Productivity Enhancement Program
CNC	Computer and Numerically Controlled Machine
DA	Department of Agriculture
DOST	Department of Science and Technology
ESEP	Engineering and Science Education Project
ITDI	Industrial Technology Development Institute
MLP	Manufacturing Linkage Program
MNAAP	Medium-Term National Action Agenda for Productivity
MNC	Multinational Corporation
MPEX	Manufacturing Productivity Extension Program
MTPDP	Medium-Term Philippine Development Plan
NEDA	National Economic and Development Authority
NSDB	National Science and Development Board
NSTA	National Science and Technology Authority
PCHRD	Philippine Council for Health Research and Development
PTFST	Presidential Task Force on Science and Technology
RDC	Research and Development Center
R&D	Research and Development
SEI	Science Education Institute
S&T	Science and Technology
SME	Small and Medium Enterprise
STAND	Science and Technology Agenda for National Development
STCC	Science and Technology Coordinating Council

STII	Science and Technology Information Institute
STMP	Science and Technology Master Plan
TAPI	Technology Application and Promotion Institute
TESDA	Technical Education and Skills Development Authority
TRC	Technology and Resource Center
TVET	Technical and Vocational Education and Training
UNDP	United Nations Development Programme
UP	University of the Philippines

Abstract

National innovation system is anchored on the theory that industrial development requires technological capability in industry, and that exploitation of technology is most critical at the firm level.

This paper describes the structure and characteristics of the Philippine innovation system and compares it with those of the United States, Japan, and Germany. It concludes that the Philippine innovation system must gear up to the requirements of a catch-up system to fit its institutions to its economic structure. This requires all the elements of the system to address the technological capability, adaptation, assimilation, and modification needs of a catch-up economy.

I

Introduction

Industrial development requires technological capability in industry. The national innovation system (NIS) is anchored on the theory that industrial development requires technological capability in industry, and that the exploitation of technology is most critical at the firm level. National policies can build and develop the technological capability of domestic firms. The recent internationalization of business has convinced policymakers and managers to view national innovation systems as strategic assets in global economic competition.

The objective of this study is to describe and analyze the structure and characteristics of the Philippine innovation system. This paper uses international best practices in the national innovation system in evaluating the effectiveness of the Philippine innovation system and in recommending policies to improve the system.

This report is organized as follows. The next section begins with a discussion of the theory and methodology of national system of innovation. The succeeding four sections describe the structure and characteristics of the Philippine, American, Japanese, and German innovation systems, respectively. The ensuing section briefly highlights the strengths and weaknesses of the American, Japanese, and German innovation systems. Another section evaluates the gaps and effectiveness of the Philippine innovation system. Still another section diagnoses some policy issues. The last section discusses the relevant conclusions and recommendations.

II

Methodology

The theoretical framework used to analyze the NIS varies. List (1959) considers the need for government responsibility for education and training (and for protecting "infant industries") as an important element of his concept of NIS. He also sees the necessity of creating an infrastructure supporting industrial development. Freeman's (1987) concept of national system of innovation refers to the organization of research and development (R&D) and of production in firms, the role of government, the interfirm relationships, and the interaction between them. His NIS theory is simply based on modern innovation theory. Nelson (1987, 1988) focuses his analysis on the combined public and private character of technology and the role of private firms, government, and universities in the production of new technology. Porter's (1990) four different determinants (firm strategy, factor conditions, demand conditions, and supporting industries) affecting the competitiveness of a national industry may be considered comprising another framework for NIS. Porter postulates that the competitive advantage of a nation consists of those national attributes that foster competitive advantage of some of its industries. The competitive advantage of nations can be analyzed in terms of their clusters of industries, and Porter's mix-of-cluster approach is a useful tool for an empirical comparison of NISs. Lundvall (1992) extends Porter's framework by explaining the link between learning and innovation. He asserts that learning is predominantly an interactive and socially embedded process, which cannot be understood without considering its institutional, economic, and cultural context. While Porter considers national systems as environments to individual industries involved in international competition, Lundvall focuses on the workings of the national system in its own right. Nelson (1993) presented 14 country-specific case studies in an attempt to portray the historical interplay of social, political, institutional, economic and cultural factors in shaping current innovation systems.

The approach of this study is based on the Freeman framework, which focuses on the interaction between the production system and the process of innovation. This approach addresses the issue of which organizational forms are most conducive to the development and efficient use of new technology, not the budgetary, institutional, and policy constraints that can get in the way of government efforts to promote innovation. NIS is an analysis of the specific systemic context in which a national government intervenes.

III

The Philippine Innovation System

The government created the National Science and Development Board (NSDB) in 1958 to formulate and implement science and technology (S&T) policies, and to coordinate S&T agencies. In 1974, a national science development plan was incorporated in the Medium-Term Philippine Development Plan (MTPDP): 1974-1977. All succeeding MTPDPs contained a chapter or sections on S&T policies, plans, and programs. In 1982, the NSDB was reorganized and renamed National Science and Technology Authority (NSTA). Under this setup, S&T councils were created to formulate sectoral policies, programs, and strategies, and allocate funds for specific fields. In 1986, the Department of Science and Technology (DOST) was created from the restructured NSTA.

The following agencies were created under the DOST structure:

1. Technology Application and Promotion Institute: promoted the commercialization of technologies
2. Science Education Institute: formulated plans for the development of S&T education and training
3. Science and Technology Information Institute: maintained S&T data system
4. Industrial Technology Development Institute: undertook applied R&D in industrial manufacturing, mineral processing, and energy
5. Advanced Science and Technology Institute: undertook R&D in high-technology areas.

In 1988, the Presidential Task Force on Science and Technology (PTFST) was created to formulate the Science and Technology Development Plan. In 1989, the Science and Technology Coordinating Council (STCC) was created to implement the recommendation of the PTFST.

The DOST introduced the Science and Technology Master Plan (STMP) in 1990, which set the goals and objectives for the S&T sector, and provided a framework for the effective coordination of S&T projects and programs consistent with national development policies. STMP cited the following major problems in the S&T sector: (a) underutilization of S&T for development, as reflected in the low quality and low productivity of the production sector and heavy dependence on imports; (2) underinvestment in S&T development in terms of manpower training, technological services, R&D facilities and financial resources; and (3) weak linkages between technology generation, adaptation, and utilization.

The three main strategies of the STMP are: (1) modernization of the production sector through massive technology transfer from domestic and foreign sources; (2) upgrading of R&D capability through intensive activities in high-priority sectors; and (3) development of S&T infrastructure, including institution building, manpower development, and development of S&T culture.

The Comprehensive Technology Transfer and Commercialization program was initiated to disseminate and commercialize locally developed technologies. But there was a lack of locally developed commercially viable technologies. There was little government-private sector joint research ventures, and government budgetary constraints made it impossible to implement the S&T infrastructure projects.

The MTPDP for 1993-1998 targeted an increase in R&D expenditures from 0.24 percent of GNP in 1992 to 1 percent of GNP in 1998. However, the priority activities in support of this goal were not adequately implemented. For instance, activities such as (1) modernization of production facilities in technology-based industries; (2) global technology search to acquire foreign technology in the priority areas; (3) provision of S&T services (e.g., standards, quality control, chemical and physical analysis, etc.); and (4) transfer and commercialization of technologies for the development of competitive industries have yet to be visibly felt in the industrial sector.

In 1993, DOST replaced STMP with the Science and Technology Agenda for National Development (STAND). STAND s objective was to help realize the vision of Philippines 2000 by focusing S&T activities on export niches identified by the private sector. While STMP identified 15 priority sectors, STAND identified seven export winners, 11 basic domestic needs, three support industries, and the coconut industry. STAND identified six specific strategies: (1) to increase private sector participation in S&T activities; (2) to develop emerging technologies; (3) to promote government-industry-academe linkages; (4) to develop S&T manpower; (5) to review S&T policies; and (6) to promote technology monitoring, assessment, and forecasting. Specific products and processes are being identified for R&D in the STAND through programs coordinated by DOST-approved product managers working in consultation with academe, government and private sector. The assistance of experts from private organizations (local and foreign) has been enlisted by DOST under the United Nations Development Programme (UNDP) funding support. A UNDP-assisted project, "Achieving International Competitiveness Through Technology Development and Transfer," was undertaken for DOST by outside experts in 1995. The Manufacturing Productivity Extension (MPEX) Program of DOST assists SMEs in sourcing their technological requirements and improving their productivity. DOST's Consultancy in Agriculture for Productivity Enhancement (CAPE) Program facilitates the transfer of technologies to the farmers. The most current program for DOST to build scientific and technological capability refers to the Education and Science Education Project (ESEP), which is supported by a program loan from the World Bank. It is envisioned to build and upgrade scientific and engineering expertise and facilities in selected engineering and science institutions. The ESEP includes a Management of Technology program, which aims to build and upgrade the managerial expertise of scientific and technical decisionmakers. In addition, it provides assistance for the upgrading of science and mathematics teaching in selected secondary schools in the Philippines. By June 30, 1998 ESEP had produced 3,554 short-term trainees, 1,077 diploma degree holders, 513 master s degree graduates, and 51 Ph.D. graduates. A total of 72,296 books and library materials and 569 journals were delivered to participating institutions. Thirty laboratories in tertiary institutions were upgraded, and 110 high school laboratories were built. There is still no thorough assessment of the extent to which ESEP has successfully met its objective of developing science and technology manpower in the Philippines.

As seen in Table 1, R&D expenditures (in current terms) increased by 23.1 percent on an annual basis between 1989 and 1992, and by 17.2 percent between 1993 and 1996. On the average, the government provided 52.7 percent of the R&D expenditures during the 1989-1992 period, and 62.9 percent between 1993 and 1996. Industry support provided approximately 26 percent of total R&D expenditures during

Table 1. R&D expenditures by major sectors: 1989–1996 (at current prices in thousand pesos)

Sector	1989	1990	1991	1992
Higher Education	210,840	274,793	290,047	433,234
Government	903,503	705,908	1,019,628	1,728,348
Nongovernment	130,867	162,779	135,713	136,866
Private Industry	393,491	511,264	523,288	642,101
Total	1,638,701	1,564,744	1,968,676	2,940,549
	1993	**1994**	**1995**	**1996**
Higher Education	380,029	419,801	457,063	531,981
Government	1,036,304	1,131,363	1,433,187	1,742,483
Nongovernment	155,626	170,442	207,700	249,918
Private Industry	547,484	599,603	730,677	879,195
Total	2,119,444	2,321,210	2,828,628	3,403,577

Sources: DOST, National Survey of Scientific and Technological Activities: Integrated Report (1992); Cororaton et al. (1998).

the 1989-1996 period. In short, government agencies contributed the biggest share to total R&D expenditures.

Fulltime R&D manpower totaled 9,719 in 1992 and 9,896 in 1996. Total manpower increased by an average annual rate of 3.2 percent during the 1989-1992 period, and 9.4 percent from 1993 to 1996. Fulltime R&D manpower increased at an average annual rate of 4.3 percent over the 1989-1992 period and 8.3 percent over the 1993-1996 period. In both parttime and fulltime manpower, government agencies utilized the biggest number of R&D personnel. The private sector contributed only 11.3 percent of total R&D manpower for the 1989-1996 period (Table 2). Most of the R&D personnel have bachelor degrees, and those with Ph.D. degrees have a negligible share. R&D personnel with Ph.D. degrees are dominated by those in the social sciences, and consist of 10 percent from the engineering and technology fields.

This analysis shows that the public sector provides the bulk of R&D expenditures and personnel. Policy reforms in the S&T sector must therefore address the need to significantly increase the share of private R&D in the Philippines.

Table 2. R&D personnel by major sectors: 1989–1996

Sector	1989	1990	1991	1992
Higher Education	6,772	6,824	6,876	6,929
Government	4,948	5,034	5,919	6,065
Nongovernment	843	893	896	922
Private Sector	1,646	1,630	1,652	1,694
Total	14,209	14,381	15,343	15,610
	1993	1994	1995	1996
Higher Education	5,384	6,177	6,363	7,027
Government	4,298	4,931	5,080	5,609
Nongovernment	701	804	829	914
Private Sector	1,297	1,487	1,532	1,692
Total	11,679	13,399	13,804	15,242

Sources: DOST, National Survey of Scientific and Technological Activities: Integrated Report (1992); Cororaton et al. (1998).

Note: R&D personnel refers to the sum of fulltime and parttime individuals in each category.

DOST is coordinated by five sectoral planning councils (covering the areas of agriculture and forestry, health, aquatic and marine resources, industry and energy, and advanced science and technology); seven R&D institutes (covering industrial technology; nuclear research, forest products, food and nutrition, textile, metals, and advanced science and technology); and six S&T service agencies (focusing on science education and training, information networks, commercialization of technology, weather forecasting, and volcanology and seismology). An intercouncil committee coordinates the five councils.

IV

The American Innovation System

The organization and finance of innovation in the United States have evolved considerably during the past 80 years. One distinguishing feature of the U.S. innovation system is the enormous scale of its R&D investment. Industrial research activity during the early twentieth century was dominated by the chemicals and related industries (chemicals, glass, rubber, and petroleum), which accounted for nearly 40 percent of the number of laboratories founded during 1899-1946, and more than 40 percent of total research scientists and engineers employed in manufacturing in 1921. Electrical machinery and instruments accounted for more than 20 percent of all scientists and engineers employed in industrial research in U.S. manufacturing in 1946. Thus, the major prewar research employers were the research-intensive industries (chemicals, rubber, petroleum, and electrical machinery), which accounted for at least 60 percent of the professionals employed in industrial research during the period 1921-1946, and which were geographically concentrated in five states: New York, New Jersey, Pennsylvania, Ohio, and Illinois (Mowery and Rosenberg 1993).

Between 1921 and 1946, inhouse industrial research had supplanted the inventor-entrepreneur, and reinforced the dominant position among the largest 200 firms. Federal antitrust policy prevented large firms from acquiring small technology-intensive firms. Large firms invested heavily in industrial research during this period as a survival strategy. Consequently, federal antitrust policy may have paradoxically aided the survival of U.S. large firms and the growth of a stable, oligopolistic structure in some U.S. manufacturing industries.

Industry accounted for about two-thirds of total R&D expenditures throughout the 1930s; federal expenditures constituted at most 20 percent; and the remainder came from universities, state governments, private foundations, and research institutes. Industrial and academic research were developed in parallel in the U.S. in the late nineteenth century due to the example set by German industry and academia. State governments provided public funding for many U.S. universities. State governments' contributions to university research had exceeded the contribution of the federal government during this period because both the curriculum and research of U.S. public universities were closely geared to the requirements of the local economy. The expansion in the number of engineering schools and programs in the second half of the 19th century accelerated the use of scientific knowledge in industry. The training of engineers was often elementary in character, and few U.S. universities before 1940 engaged in scientific research at the frontier. It was the larger body of scientific knowledge (not frontier science) that was relevant to the needs of an expanding U.S. industrial sector. The number of people bringing the knowledge and methods of science to bear on internal problems was vastly large. This helped the scientific and engineering "catch up" in the U.S. during the early twentieth century, and which likewise aided the diffusion and utilization of advanced scientific and engineering knowledge (Mowery and Rosenberg 1993).

Another distinguishing feature of the U.S. innovation system before World War II was its heavy reliance on the linkage between industry and agriculture (e.g., the development of advanced technologies for food processing and its technological superiority in farm machinery and equipment). Much of the growth in U.S. agricultural output per capita during the pre-1940 period depended on the expansion of cultivated land and the dissemination of seed strains that were suited to local growing conditions. During this period, a sizable portion of the budget was devoted to extension activities (e.g., testing, demonstration, and dissemination of best practices in agriculture; and modification of seeds, techniques, and equipment to fit local conditions). By 1940, scientific research was more important than extension. Advances in biology and chemistry research were exploited and were responsible for rapid agricultural productivity growth during this period (Mowery and Rosenberg 1993).

In the postwar period, the support of the federal government for U.S. basic, commercial, and military research expanded dramatically. Nongovernmental institutions retained responsibility for the performance of much of the U.S. R&D in the postwar period. In contrast, federal government s R&D went to support research performed within the federal establishment itself in the prewar period. This reflects the far more advanced state of development of university and private sector research capabilities in the postwar period. Federal R&D spending has been a large fraction of national R&D investment during the postwar period (total R&D spending ranged from slightly more than 1 percent of GNP to almost 3 percent of GNP). In recent years, most of basic research was performed in universities and federally funded research and development centers, which were administered by universities and colleges. However, most of the support for basic research was provided by a small number of federal agencies: Department of Health and Human Services (particularly the National Institutes of Health), National Science Foundation, Department of Defense, Department of Energy, and the National Aeronautics and Space Administration. The military R&D spending dominated the federal R&D budget for the last 30 years of the postwar period and was far more development-intensive than the rest of the federal R&D budget. Defense procurement likewise lowered barriers to entry and allowed the entry and rapid growth of numerous young and relatively small firms in the computer industry (Mowery and Rosenberg 1993).

Another feature of the structure of the postwar U.S. research system was the expansion of research in U.S. universities due to expansion in federal support making U.S. universities the centers for the performance of scientific research. Federal support for university research covers both the demand side (contracts and grants for specific research projects) and supply side (acquisitions of physical equipment and facility needed to both teach and undertake high-quality research, and financial aid for students in higher education). Federal support for research therefore strengthened the university commitment to research and reinforced the link between research and teaching.

Still another feature of the postwar U.S. research system was the role of small startup firms in conceptualizing new technologies, particularly in computer, microelectronics, and biotechnology industries. High levels of labor mobility within regional agglomerations of high-technology firms served as an important channel of technology diffusion. In addition, a vigorous U.S. venture capital market supplemented by public equity offerings played an important role in support of new firms during their infancy. Moreover, a relatively permissive intellectual property regime in computer, microelectronics, and biotechnology industries aided the conceptualization of innovations by new firms in terms of facilitating technology diffusion and reducing the burden on new and young firms of litigation over innovations that might have originated in part within established firms. Postwar U.S. antitrust policy likewise assisted startup firms due to liberal-patent-licensing terms of the consent decree of the 1956 settlement of the AT&T case (microelectronics) and the IBM case (computer). Postwar antitrust policies likewise discouraged established firms from acquiring high-technology smaller firms. Military procurement from startup firms also enhanced further the possibilities of substantial technological spillovers from military to civilian applications (Mowery and Rosenberg 1993).

In the 1970s, returns to R&D investments and the rate of growth in real industry expenditures on R&D declined too due to competitive pressures from foreign firms, increases in the real cost of capital, and slowdown in the growth rate of the U.S. economy. Industry funding of basic research declined and many of the central research facilities of the giant corporations redirected R&D resources away from longer-term activities and toward development projects that were more likely to produce near-term commercial payoffs (Rosenberg and Mowery 1993; Lester 1998).

The international environment changed drastically in the 1980s, affecting adversely the U.S. innovation system. The process of economic and technological convergence reduced the gap in per capita income, productivity, and R&D investment between the U.S. and many major industrial economies. More sophisticated foreign firms emerged in the market, and U.S. superiority in high-technology markets was eroded. Private firms responded to these environmental changes by pursuing other external ways of exploiting R&D such as cooperative research programs with foreign or domestic firms and university-industry research linkages. On the other hand, the federal government undertook new initiatives in research funding, trade policy, and intellectual property protection to increase the domestic economic returns to public and private R&D investments in the U.S.

In the 1980s the structure of the U.S. industrial research system also changed considerably. The dominance of inhouse corporate research laboratory may have declined and the role of new firms in the commercialization of new technologies may have been reduced. New startup firms in high-technology industries are prone to pursue technology commercialization through collaboration with larger domestic or foreign firms instead of pursuing the goal independently. The U.S. venture capital market is now excessively focused on short-term results and is providing insufficient support for long-term technology development. Venture capital market is likewise described to have become a less important source of support for startup firms due to the increasing costs of new product development. Established U.S. and foreign firms are increasingly acquiring startup firms because of the changing public policy environment in the U.S., which has relaxed its antitrust policy that previously discouraged acquisitions of startups by large industrial firms. Efforts to strengthen domestic protection for intellectual property may reduce the viability of startup firms (at least in the computer industry). The U.S. military is no longer a strategic player in the market for computer and semiconductor, and the possibilities for military-civilian technology spillovers have declined.

All of the above structural changes appear to reduce the main elements that distinguish the U.S. national innovation system from those of many other nations.[1]

[1]This section draws heavily from Mowery and Rosenberg (1993).

V

The Japanese Innovation System

During the Tokugawa regime, which secluded Japan from the rest of the world from 1639 to 1854, trade was restricted to the Chinese and the Dutch. The Dutch provided the government with information on many aspects of science and technology, which were translated into Japanese and diffused to other feudal lords. The literacy rate in Japan was likewise high in the 17th and 18th centuries because of the existence of two school systems: (1) schools owned by the feudal local governments and (2) private schools, many of them run by Buddhist temples. Thus, the technological level of Japan was not too much behind the West, and the establishment of the public education system in the Meiji Era (1868˘1911) was smooth, because the educational infrastructure was already in place. Higher education system (particularly technology and engineering education) was developed, with the help of British professors, in the nineteenth century. During this era, the Japanese government also built and owned plants and factories in railroad, mining, shipbuilding, machinery and textile industries. Technology transfer was made through the following channels: importing technology, hiring foreign engineers and specialists, and importing machines and plants. At the same time, indigenous technology complemented imported technology by providing the ability to assess the various technologies available from the west, and the capability to adapt them to domestic conditions (Odagiri and Goto 1993; Hoshino 1982).[2]

The Japanese scientific and engineering infrastructure was developed in the 1914-1945 period. Several universities and other

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[2] Caves and Uekusa (1976) reported that a survey of Japanese manufacturers showed that, on average, one-third of the respondents' expenditures on research and development was allocated to building the capacity to know what technology was available for purchase or copy, and the ability to modify and adapt foreign technology to domestic use.

higher education institutions were established and supplied many trained engineers. Trading companies were used as channels of information and supplied foreign books and journals. More vocational schools were established, which developed a greater supply of skilled workers who were capable of handling advanced equipment. Basic research institutions (e.g., national industrial laboratories and corporate R&D laboratories) were created to serve the needs of technology-based industries. Government took measures to expand rapidly scientific and technological departments at universities and set up a variety of new research laboratories after the war began. The Science Council was established in 1933 to increase research funds for universities and other research institutions, and to promote efficient research management. For instance, the grants provided by the Science Council encouraged and financed projects undertaken by researchers belonging to different institutions. The development of scientific and technological infrastructure, complemented by increasing production and R&D activities provided the environment for the development of world-class Japanese manufacturing industries (Odagiri and Goto 1993; Hashimoto 1999).

At the end of World War II, Japan realized that although two-thirds of its production capacity was not destroyed, its production skills and R&D knowledge were obsolete. So Japan developed the catch-up program all over again by implementing a two-pronged strategy: (1) importation of advanced technology and (2) promotion of a domestic technological base. Industrial policy was implemented. Scarce foreign currency was allocated to firms capable of adapting and improving imported technology. Restriction on imports and of foreign direct investment was imposed. This policy forced foreign firms to exploit their technological superiority by selling their technology. Japanese firms, on the other hand, were given only the option of importing technology. Industrial policy was successfully implemented in Japan because firms which imported technology invested in inhouse R&D facilities, and were eager to import technology because of expectation of high returns (Odagiri and Goto 1993). However, technology assimilation was not smooth. Organizational infrastructure had to be created to train managers and workers to properly use modern methods and techniques, and to adapt to modern organized management practices (Hoshino 1982).

Since the 1960s, the Japanese have observed that the terms of technology imports became less favorable, so they emphasized domestic R&D capability through the use of incentives such as tax breaks, subsidies, and low-interest loans. This policy shift resulted in the decline of government support of industrial R&D and in the substantial increase in the R&D expenditures of private firms. Joint or cooperative research efforts were encouraged. Japanese science and technology efforts shifted its emphasis to the promotion of basic research and the globalization of innovation. The following features of management in Japanese firms also contributed to a rapidly changing and R&D-intensive environment: (1) a bias toward growth maximization; (2) familiarity of management with research, production, and marketing; (3) close links between R&D, sales, and production departments; and (4) smooth transfer of new processes and products into production, partly due to a policy of lifetime employment in big firms that give incentives to provide internal training and practice internal promotion (Odagiri and Goto 1993).

Takahashi (2001) argues that Japan's failure to respond to the digital age is one of the causes of the decline in the competitiveness of its high-technology industries. Another cause is the changing proportion of science- and engineering-driven industries. Science-driven industries aim to commercialize new scientific discoveries, while engineering-driven industries aim to produce new products and services by exploiting the existing stock of knowledge. The emergence of dominant design is a sign that an industry has shifted from the science-driven phase to the engineering-driven phase. Japan is good at engineering-driven industries because these industries fit the country's institutions, which revolve around collective knowledge creation. On the other hand, science-driven industries (e.g., biotechnology) require individual creativity. Basic research is useful in science-driven industries, while research on generic technologies is important in engineering-driven industries. Government and foundations finance basic research in science-driven industries, while the private sector finances applied research and development in engineering-driven industries. Integrated assembly is the appropriate organizational form for engineering-driven industries, while a single-venture mission is the appropriate one for science-driven industries. The appropriate form of organization in the information-technology industry has changed from one of integrated-assembly to one of a single mission. American companies have restructured their operations to fit this changing environment. However, the majority of Japanese manufacturers remain as integrated organizations. This failure to restructure explains the loss of competitiveness by Japanese companies in this industry because it “deprived them of the speed of development and [the] freedom to procure various parts at reasonable cost” (Takahashi 2001).

VI

The German Innovation System

In the nineteenth century, Germany turned to Britain and Belgium for technical know-how, new machinery, and skilled workers in the machine building and iron and steel industries. The German government often provided financial support for the purchase of foreign machines, which were used as demonstration materials in local R&D laboratories. Government-financed system for education and research in technology, science, and business was pioneered in Germany and was a major social innovation in the nineteenth century. The university was the institutional focus of scientific research in Germany. In addition, academies of science were founded in several German states, which were primarily tasked to pursue scientific research. However, many universities were in a poor state to undertake scientific research. Some German state governments reformed their universities; others established new ones with better curricula; professors were hired based on their reputation derived from their publications. Professorial chairs were filled with the best people and provided them with adequate facilities. University research in Germany, particularly in medicine, physics and chemistry, rose to world leadership; student numbers increased rapidly; and government funds for universities increased even faster than the number of students did.

German universities in the nineteenth century accomplished much for science, but ignored engineering on the assumption that the latter lacked the dignity of a science. Some engineering schools were established in the eighteenth century to train administrators in government-owned mining industry, civil engineers and architects in government service, military engineers, and artillery officers. In the 1820s, polytechnic schools were established to train technicians for private industry. Several levels emerged in the vocational and technical education system: apprenticeship system, middle-level schools, and university level. The polytechnic schools raised entrance requirements, improved their teaching, and gained social recognition when their graduates were accepted for public service. In the 1870s, the polytechnic schools were called "Technische Hochschulen," and were elevated to higher status that required similar entrance examinations as the universities. In 1899, the Technische Hochschulen was given the right to grant doctoral degrees. Around 1900, business schools were established and were later developed into university-level institutions. Middle level schools were likewise established. Thus, a system of business education emerged with several levels: apprenticeship system, middle-level schools, and university-level institutions.

At the beginning of the twentieth century, Germany had established a sophisticated education system covering all levels, with emphasis on technology, science, and business. Universities and Technische Hochschulen produced relatively high-quality research, and university-industry links were enhanced. German colleges and universities graduated 30,000 engineers compared to about 21,000 in the U.S. in the first decade of the twentieth century. In addition, central government and federal states established and financed some 40 to 50 research institutes in applied areas (e.g., weather and atmosphere, geography and geology, health, agriculture, shipbuilding, biology, fishery, etc.) and basic areas (e.g., physics, chemistry, medicine, etc.) which complement the universities research capabilities in these areas. The Kaiser-Wilhelm Society was established in 1911 to tap industry as a source of research funds. Five institutes were established: the Institutes for Chemistry, Physical Chemistry, and Coal Research were mostly financed by industry, while the Institutes for Biology and Experimental Therapy were jointly funded by the government and industry; the government's contribution was in the form of land and salaries of some of the Institutes' staff.

Germany was the largest exporter of pharmaceuticals, dyestuffs and synthetic fertilizers in the 19th century because it relied heavily on technological innovations emanating from chemical, medical, and biological research at the universities and research institutes. Toward the end of the 19th century, when electric power technology was introduced, German firms assumed technological leadership in new industries (e.g., iron and steel, metal processing, electrotechnical, combustion engine) because of its sophisticated education and research system.

After the Second World War, Germany was divided into East and West Germany. Large parts of Germany's industrial facilities were destroyed, and the basic components of the West German innovation system were reconstructed. The Kaiser-Wilhelm Society became the Max Planck Society in 1948; and the trade union structure was introduced to limit trade union conflicts within firms and industries.

The Max Planck Society (composed of 60 institutes in 1989) is financed by central government and federal state governments on a 50-50 basis. Eighty percent of the funds are concentrated in research in the natural sciences performed by leading scientists recruited from universities. Unlike its predecessor, the Kaiser-Wilhelm Society, which focused on applied research (e.g., textile research, leather research, etc.), the Max Planck Society focused on basic research. The Fraunhofer Society filled the gap left by the Max Planck Society by providing a strong link between universities and industry and concentrating in applied research, serving clients from industry and government on project contract basis.

At present, Germany could be commended for having a portfolio of exports spread over many product groups: machinery, motor vehicles, chemicals and pharmaceuticals, scientific instruments, metal products, telecommunications, power generating equipment, and iron and steel. Industry, not the government, is the major source of R&D funds. However, the higher education system is no longer a showpiece in Germany's innovation system. Germany has neglected its higher education system since the mid-1970s. A governance system must be introduced to give universities more responsibilities and provide them with incentives to be more efficient. A strong university system will provide not only a solid base for Germany's innovation system but also the capability for technological innovation in the future. Germany must also prepare to accommodate the internationalization of business and the globalization of innovation.[3]

[3] This section draws heavily from Keck (1993).

VII

Understanding the Fundamentals

Japan's national system of innovation differs from the U.S. in three aspects:

1. *The role of small companies.* Large corporations account for a much larger share of innovations in Japan, while small newly established firms generate a steady stream of technological breakthroughs in the U.S.
2. *The role of government in promoting R&D.* Japanese government spends far less to support private sector R&D than its U.S. counterpart. Corporate funding for R&D is significant in Japan, but government-funded research accounts for nearly 50 percent of the total R&D expenditures in the U.S.
3. *The nature of advanced training for R&D personnel.* Japan relies heavily on inhouse apprenticeship and permanent employment, which is more cost-effective, but is not as rigorous academically as that in the U.S. On the other hand, the quality of university-based research in Japan is low compared to that in the U.S. Furthermore, university-industry linkages are far more extensive and transparent in the U.S. than they are in Japan. The lower levels of interfirm labor mobility in Japan (partly due to the practice of lifetime employment in large corporations) restrict technology transfer. However, the Japanese innovation system promotes cooperative research projects to offset the negative effect of labor-market practice on the transfer of technology. On the other hand, continuity in personnel plays a key role in successfully managing innovations in Japanese companies. The practice of moving personnel along with the innovation from research to commercialization promotes interaction across the various stages of innovation, and facilitates the integration of a large

amount of tacit knowledge embodied in process development (Hane 1999).

The strongest feature of the Japanese innovation system is the fast pace of domestic adoption of new technology in manufacturing. This is because the system has consistently supported domestic technology adoption and strong domestic competition in technology commercialization. Technology adoption and technology diffusion from existing knowledge have been adroitly pursued by the Japanese innovation system during the technology catch-up stage. Now that it has reached the technology leadership stage, the Japanese innovation system has emphasized basic research or the generation of new knowledge from frontier science.[4] Shifts in industrial structure have also been very drastic in Japan. Barriers to entry into new and growing industries have been lowered in the era of liberalization and internationalization of business. Thus, a Japanese firm must innovate to survive.

Japan's effective innovation system is helped by its latecomer advantage and government policies. However, the most important element of its success is attributed to the willingness of its private sector (investors, managers, engineers, and workers) to respond to the opportunities open to them, to start an unfamiliar business, and to adopt and assimilate new technologies.

The strength of the German innovation system, on the other hand, lies in the institutional forms which they pioneered in the 19th century: (1) research-oriented university that combines its educational function with the advancement of scientific knowledge; (2) science-based firm with inhouse R&D separated from production; (3) a comprehensive system of technical education; (4) specialized research institutes in applied areas; and (5) academies of science, professional associations, and nonprofit foundations for scientific research.

The German innovation system likewise efficiently established and implemented government-funded national laboratory systems to solve scientific and theoretical problems of great importance to the society and which required more resources (capital, researchers,

[4] Although there is rapid increase of basic research conducted by Japanese universities and colleges, as well as an increased role of basic research within Japan's R&D efforts, Japan's total effort in basic research remains modest by U.S. standards (Okimoto and Saxonhouse 1987).

instruments, materials, working time) than can be provided by corporate R&D centers and educational institutions.

The weakest link in the present German innovation system is the neglect of the higher education system since the 1970s, resulting in increased student population but decreased personnel and real expenditures. Institutional reforms are needed to address the inadequacy in teaching and research. The existing structures to coordinate the technical and scientific efforts of the universities are deficient. For instance, the split of the former Ministry for Scientific Research into Ministry for Education and Science (responsible for R&D undertaken in universities) and Ministry for Research and Technology (responsible for R&D outside the higher education sector) had made coordination of the innovation system more difficult and more fragmented.

The Philippine innovation system can emulate from the institutional forms established in the United States, Japan, and Germany. It can adapt a few of them, and sometimes improve them to address the country's needs and advance technological development.

VIII

Improving the National Innovation System

The major components of the national innovation system are firms, universities, technical-vocational institutions, technological information infrastructure, research and development centers (RDCs), technology and resource centers (TRCs), financial system, and government (Figure 1).

Firms

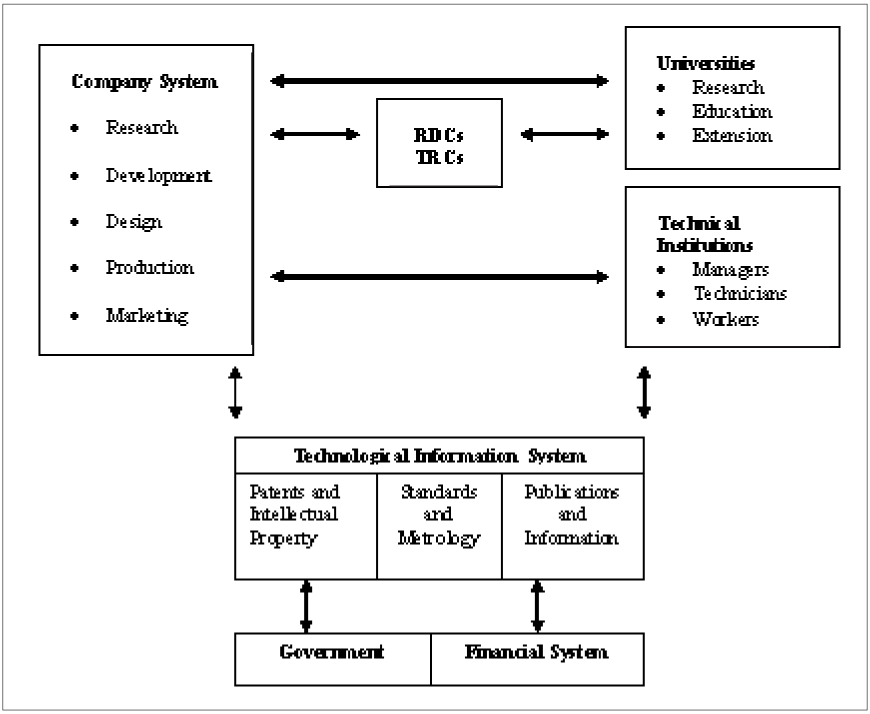
The internal organizations of firms are the critical components of the structure of the national innovation system. Most innovations are developed and adopted by firms. The organization of the flow of information and of the learning process influences the innovative capability of a firm. In particular, the linkage between sales, production, and R&D departments of the firm is an important aspect of the innovation process. Interfirm relationships (i.e., competition and cooperation) are other important aspects in the structure of the national innovation system.

The resource-based theory that applies to firms asserts that bundles of resources lie at the heart of a firm's competitive advantage (Penrose 1959 and Barney 1997). The ability of a firm to adopt and exploit technology depends on its internal capabilities. Arnold (1995) classifies four levels or phases in the development of firm-level technological capabilities: (a) low-technology small and medium enterprises (SMEs), (b) bootstrappers, (c) technological competents, and (d) research performers.

Low-tech SMEs have no technological capability and have no need for it. Bootstrappers hire a minimum of one person (usually an engineer) to monitor and understand the significance of technological changes happening outside the firm. Technological competents possess enough capability to do serious development work and participate in technology networks. Research performers take a long-run view of R&D capabilities. There are two types of research performers: (a) large domestic firms and multinational corporations (MNCs) with internal R&D departments, and (b) high-technology small startup firms located in science parks or spinoffs from university-industry cooperative research. In focusing on the private sector's demand for technology, low-tech SMEs and bootstrappers are inclined to obtain their technical inputs from suppliers of machinery and raw materials. Technological competents and research performers are the types to locate in science parks, participate in domestic or international research consortiums, or involve in university-industry linkage programs.

Gutierrez (2002) has surveyed potential investors in the proposed UP Diliman Science and Technology Park, and reported that 73 percent of the respondents are local companies while 23 percent are subsidiaries of MNCs (companies that fit Arnold's stereotypes of "technological competents" and "research performers"). Tanchanco

Figure 1. Major components of an innovation system



(2001) provides a list of products in the seafood, fruits/vegetables, rootcrops, and other fruits sectors, most of which were developed by government institutions (DOST, Department of Agriculture or DA, the Bureau of Fisheries and Aquatic Resources or BFAR and universities including UP Diliman and UP Los Baños).

A private sector response to exploit commercial opportunities is exemplified by Pascual Laboratories. The company has established a subsidiary called Altermed to adopt and commercialize two herbal products developed by the National Integrated Research Program on Medicinal Plants under DOST's Philippine Council for Health Research and Development (PCHRD). Altermed is engaged in the production of *lagundi* under the brand name Ascof, and *sambong* under the brand name Releaf. Ascof is available in 300-mg. plain and 600-mg. forte. Releaf is available in 250-mg. plain and 500-mg. forte. *Lagundi* is an anti-cough and anti-asthma product while s*ambong* is used as a remedy for urolithiasis, a urinary ailment (Ancog 2001).

The development of herbal medicine is part of the national policy of self-reliance.

MNCs dominate 65 percent of the domestic pharmaceutical market. The literature on technology transfer promotes the idea that foreign direct investment is one of the channels of technology transfer to local companies. However, MNCs prefer direct investment rather than licensing, especially when it involves new and most profitable technologies. Local firms' only chances of gaining access to technology may lie in reverse engineering, or hiring of former MNC employees with special skills. The effectiveness of the reverse engineering strategy is questionable because local firms may lack the technical skills required to imitate the newest and most profitable technologies (Blomstrom and Kokko 2001). This was not the strategy followed by Pascual Laboratories. It scanned locally available technologies, adopted it, and commercialized two products developed by a government RDC. A case of private exploitation of government-funded R&D.

Universities

Universities are the primary source of new skills, new knowledge, and new ideas, which make substantial and direct contributions to industrial development. Research-intensive universities are expected to commercialize the creative ideas of their students, staff, and faculties and to bring the benefits of science to the public. This expectation creates different institutional responses from universities in different countries. Some universities pursue extensive links with industry; others are limited to informal faculty-firm collaboration because of constraints imposed on public universities to accept funds from private firms that have commercial interest in the outcome of their research activities. The responses of some universities are due to the internal incentives and promotion system that rewards basic and theoretical research over applied and industry-focused research.

The history of university-industry links in both Japan and the U.S. suggests that educational institutions tended to specialize in fields of science and engineering that addressed the needs of the local economy. For example, state universities geared their research and curriculum to commercial opportunities in fields such as agriculture and mining engineering, particularly for universities located in agricultural and mining states. The University of Akron in Ohio built expertise in polymers and elastomers to support Akron s tire industry. Cornell University in New York pioneered the first American electrical engineering department whose faculty and students (in collaboration with George Westinghouse) built the first municipal electric power service for the mining town of Telluride, Colorado (Mowery and Rosenberg 1993; Kodama and Branscomb 1999). In Japan, a professor in metallurgy at the University of Tokyo fixed technical problems at the two major iron mills (Kamaishi and Yawata) by redesigning the imported furnaces, supervising the state of operation, and subsequently employing his students to help improve the operation of the mills (Odagiri and Goto 1993; Kodama and Branscomb 1999; Odagiri 1999).

The trend toward university-industry cooperation has raised concerns on its impact on the tradeoffs between the public goals of education and knowledge generation and the private goal of benefiting commercially from new knowledge. The first issue deals with dissemination of information. Do industry collaborations with academia increase the diffusion of research results? Are there instances when companies cooperating with universities ask to keep information confidential, or prevent faculty from publishing research results? The second issue involves the nature of research. Will the involvement in applied research adversely affect the pursuit of fundamental research? The third issue refers to the effect of collaboration to access to university research by newcomers. Do collaborative projects based in traditional or personal networks make access transparent and open to new partners? (Hane 1999). These are some unanswered questions on the impact of university-industry collaboration.

Brooks (1996) enumerates a number of unresolved issues or questions on future research policy and strategy:

1. Will the national laboratories or nonprofit research institutions separate from universities be the principal locus of government support for addressing the competitiveness and economic performance missions, or will the main locus remain within or in close association with the research universities?
2. What are the implications for university priorities of the increased importance of the knowledge synthesis and diffusion functions compared with the previous emphasis on the creation of new knowledge?
3. What kinds of ground rules, criteria, and procedures should be developed for the extent and form of participation of government agencies in cooperative research and educational projects?
4. Given that the primary goal of public sector investment in technology creation or diffusion is net job creation in the long run, what are the implications of government support on the selection of the most appropriate institutions and technologies?
5. How can criteria for public investment in new knowledge creation or diffusion be developed to provide assurance that public funds are not displacing potential private investment, which is likely to be more cost-effective because of its greater responsiveness to markets?
6. What are the long-term implications of the priority now being given to the economic performance mission as a justification for public investment in science and technology, and of the allocation of public resources among four classes of institutions: universities, government RDCs, nongovernmental nonprofit organizations, and private industry?

The Philippine experience in university-industry collaboration is exemplified by the Manufacturing Linkage Program (MLP), which was organized in 1985 by the engineering alumni of the University of the Philippines with funding support from DOST's Philippine Council for Industry and Energy Research and Development. MLP's main goal is to strengthen the manufacturing sector of the Philippines by carrying out activities that motivate engineering students to pursue careers in manufacturing. Plant tours, seminars, summer internships, briefing sessions, and roundtable discussions are MLP's main activities intended to address the problems and specific concerns of the manufacturing industry (Aliga 2000). MLP can pursue meaningful university-industry collaboration by recruiting science and engineering faculty from universities to undertake cooperative projects with manufacturing industry engineers to develop, adapt, and improve product or process technology that would address specific problems facing the industry.

In the long run, a concept like MLP should be self-generating through financial contributions from participating firms and nonprofit foundations. In addition, MLP can generate funds by charging fees to its value-creating services such as seminars, briefing sessions, industry assessments, and information dissemination. It can also be strengthened and made sustainable by corporatizing the program; renting an office space with complete communication facilities; and hiring a core of fulltime staff to coordinate its activities. The implication of a completely private-run MLP is that it will demonstrate the private sector's willingness to respond to opportunities open to them, to cooperate with one another, and to address problems of utmost concern to the Philippine manufacturing industry via this novel institutional form.

Scientists and engineers

One common denominator in the success story of the American, Japanese, and German innovation systems is the large number of engineers and scientists their educational systems have produced during their technology catch-up period. The large number of people bringing the knowledge and methods of science to tackle industrial problems aided the diffusion and utilization of advanced technological knowledge (Mowery and Rosenberg 1993). Table 3 confirms this pattern. The number of scientists and engineers in research-intensive U.S. industries increased from 2775 in 1921 to 45,941. A similar pattern was observed in Japan. The Japanese system significantly increased the number of scientists and engineers from 2,100 in 1965 to 44,000 in 1981 (Table 4). Germany had 474,900 R&D personnel, five times larger than those of South Korea (88,764) in 1992 (Table 5).

Table 3. Employment of scientists and engineers in industrial research laboratories in U.S. manufacturing firms: 1921-1946

	1921	1927	1933	1940	1946
Chemicals	1102	1812	3255	7675	14,066
Petroleum	159	465	994	2849	4750
Rubber Products	207	361	564	1000	1069
Electrical Machinery	199	732	1322	3269	6993
Transportation Equipment	83	256	394	1765	4491
Instruments	127	234	581	1318	2246
Others	898	2460	3817	9,901	12,326
TOTAL	2775	6320	10,927	27,777	45,941

Source: Mowery and Rosenberg (1993).

Table 6 presents the number of employed persons in technical, scientific and managerial occupations in the Philippines from 1991 to 1999. Even if we assume that all of them are R&D personnel, the average annual growth rate of R&D personnel from 1991 to 1999 was at 2.9 percent—a very disappointing performance. As Table 2 shows, this is not far from reality. R&D personnel actually increased by 3.2 percent annually from 1989 to 1992, and by 1 percent annually from 1989 to 1996.

Rosenberg (1985) shows that almost two-thirds of private industrial R&D in the U.S. was concentrated in five industrial sectors in the 1980s: aerospace, electrical and electronics, instruments, computers, and chemicals and allied products. Tables 7 and 8 present data on employment in the Philippine chemical-based and steel-based industries, respectively. Employment grew at an annual rate of 2.7 percent in chemical-based industries, and 0.7 percent in steel-based industries for the 1983-1994 period.

Technical training institutions

Short-term, on-the-job, and apprenticeship training for managers, technicians, and skilled workers is provided by a system of technical and vocational institutions. This system supplies a pool of skilled manpower to new and growing firms and industries. All important

Table 4. Scientists and engineers at Japanese universities and colleges engaged in R&D: 1965-1981

Year	Scientists and Engineers
1965	2,100
1966	3,300
1967	4,100
1968	7,200
1969	7,600
1970	19,000
1971	18,000
1972	18,700
1973	33,100
1974	35,200
1975	36,400
1976	41,400
1977	45,900
1978	45,700
1979	50,200
1980	46,700
1981	44,000

Source: Okimoto and Saxonhouse (1987).

Table 5. R&D personnel in Germany: 1992

Type	Number
Government Institutes	75,900
Universities	96,000
Business Enterprises	303,000
TOTAL	474,900

Source: Klodt (1996).

Table 6. Employment in technical, scientific and managerial occupations: 1991-1999 (in thousands)

	1991	1992	1993	1994	1995
Professional, technical and related workers	1,344 (5.80%)	1,392 (5.80%)	1,398 (5.70%)	1,366 (5.40%)	1,428 (5.60%)
Administrative, executive and managerial workers	277 (1.20%)	284 (1.20%)	326 (1.30%)	358 (1.40%)	421 (1.60%)
Production and related workers, transport equipment operators and laborers	4,903 (21.30%)	5,067 (21.20%)	5,128 (21%)	5,493 (21.80%)	5,571 (21.70%)
All occupations	22,978 (100%)	23,917 (100%)	24,443 (100%)	25,166 (100%)	25,698 (100%)

	1996	1997	1998	1999
Professional, technical and related workers	1,640 (6%)	1,654 (5.90%)	1,697 (6%)	1,763 (6.10%)
Administrative, executive and managerial workers	456 (1.70%)	531 (1.90%)	570 (2%)	662 (2.30%)
Production and related workers, transport equipment operators and laborers	6,259 (22.80%)	6,506 (23.30%0	6,366 (22.50%)	6,493 (22.40%)
All occupations	27,442 (100%)	27,888 (100%)	28,262 (100%)	29,003 (100%)

Source: National Statistical Coordination Board, *Philippine Statistical Yearbook* (1998-2000 issues).

Table 7. Employment in chemical-based industries, 1983-1994

Industry	1983	1985	1988	1994
Basic Industrial Chemicals	4,466	3,976	4,462	6,783
Fertilizers	1,772	2,510	2,620	1,906
Synthetic Resins	2,026	1,697	2,481	1,800
Pesticides and Insecticides	1,341	657	1,316	1,151
Other Chemical Products	24,432	23,749	29,700	31,101
Plastic Products	16,778	10,585	17,616	25,876
TOTAL	50,815	43,174	58,195	68,617

Sources: National Statistics Office, specifically the 1983, 1988, and 1994 Census of Establishments, and the 1985 Annual Survey of Manufacturers.

Table 8. Employment in steel-based industries: 1983-1994

Sector	1983	1985	1988	1994
Iron and Steel	17,388	15,024	15,507	21,516
Nonferrous Metal	3,619	3,317	2,618	3,589
Fabricated Metal Products	19,379	14,680	21,733	29,365
Machinery	16,541	13,603	18,576	21,801
Electrical Machinery and Appliances	52,521	37,608	54,374	107,910
Transport Equipment	22,255	12,194	14,053	24,098

Sources: National Statistics Office, specifically the 1983, 1988, and 1994 Census of Establishments, and the 1985 Annual Survey of Manufacturers.

inputs to the innovation process do not come from formal science-based R&D efforts. Informal and tacit knowledge and insights of workers, engineers, and managers are likewise crucial inputs to the innovation process.

The primary provider of technical and vocational education and training (TVET) in the Philippines is the private sector offering post-secondary, nondegree courses. However, TVET graduates are not exactly the technicians and skilled workers required by new and emerging industries, or even by established manufacturing industries, because their training revolves around office and clerical work, service and sales, automotive repair, and driving. This explains why the unemployment rate of TVET graduates is higher than the national average unemployment rate (Orbeta 1999).

The effectiveness of the Technical Education and Skills Development Authority (TESDA) in coordinating the technical manpower requirements for economic development remains a major policy issue. If the private sector is not providing the appropriate skills needed for industrial development, are the public technical institutions (including technical universities like Technological University of the Philippines) doing a better job? The private sector is adequately providing computer education skills, although it needs to strengthen the technical aspect of information technology education such as computer engineering, systems integration, and software design. The institutional form of the German technical education system provides a useful benchmark in improving the Philippine technical education system.

The existing technician training system requires some improvement. For instance, for training to produce good results, the inputs from industries must be complemented by inputs from research institutions, nonprofit foundations, and universities, which may provide a better perspective on the economy's long-term requirements. A strong worker training system does not exist simply because of the short-term orientation of the industry. An ideal training system produces workers with broad training and education to better cope with technical problems and be flexible with a changing environment. However, in practice, Philippine companies simply provide minimum training for workers to do specific tasks. The reason behind this is that local managers fear that well-trained workers will transfer to other companies that are actual or potential competitors. Local companies can emulate from operations of subsidiaries of MNCs that provide better training and pay higher wages.

Research and development institutes

Institutions are needed to help link companies with external knowledge and technology. These institutions can take the form of research and development centers (RDCs) or technology and resource centers (TRCs). RDCs are institutions undertaking basic and applied research (technology generation) and extension (technology development and diffusion). RDCs are usually established to provide common R&D facilities for an industry or group of firms. On the other hand, TRCs are mainly undertaking technology diffusion of existing knowledge and are the conduits of extension services.

Some of our RDCs are duplicating the applied research activities done in TRCs, companies, and universities. On the other hand, the RDCs in the Philippines are RDCs only in name based on their legal charter, but they actually function like TRCs. TRCs are critically useful in improving the Philippine innovation system because they can focus on the following functions: a) conducting technology awareness programs (e.g., seminars, workshops, briefings); b) tracking technological trends in the industry, c) providing industry-related information to members; d) collecting market information and establishing industry database; e) offering specialized training in fields not available elsewhere in the education and training system; f) doing consulting and development work for individual firms or a group of firms; g) conducting applied research projects commissioned by members; and h) dissemination of research results.

Most companies need routine technology assistance, not information on emerging technologies and frontier science. An RDC is designed to transfer advanced technologies to industry, but most companies may not need state-of-the-art technologies that are expensive and untested. Most SMEs may need help with improving existing operations using proven technologies, and how to strengthen quality, inventory control, design, training, and marketing. A well-functioning TRC will precisely engage in activities that are recognized to be more important to SMEs. TRCs in the U.S., Sweden, Japan, Taiwan, and Hong Kong provide the following services for SMEs: technology needs assessment, problem solving, technology awareness and tracking, technology acquisition, market research, recruitment services, production management, product design and development, overseas study visits, field trips, assistance with ISO certification, inspection and testing services, consulting services, software for data processing, training, technology demonstration, technology brokerage and referral, implementation assistance, and advisory services.

Ancog (2001) reports that the technologies developed by government RDCs are simple, easy to adopt, and can be commercialized quite profitably. However, the R&D projects were chosen based on the expertise of RDCs and the interest of the scientists. It has also been reported that DOST s Metals Industry Research and Development Center has developed spin casting, spinning, computer-aided design-computer-aided manufacturing (otherwise known as CAD-CAM), computer and numerically controlled machine (or CNC), solid waste management, gemstone processing and iron furniture-making technologies. On the other end, a United Nations Development (UNDP) and DOST study (Roble 1995) concludes that most of the product technology capability intervention needed in the metal fabrication industry involves training, marketing, and promotion (Table 9). TRCs have a clearly defined purpose and customer base, and R&D projects are industry- rather than scientist-driven if government TRCs (masquerading as RDCs) have a corporate structure and gradually shift their dependence from government support to industry support.

Thus, TRCs are the institutions created to apply existing technology and not to develop new technology. Great Britain lost its technological leadership by the end of the 19th century because British institutions were incapable of diffusing innovations and using them in a wide variety of new applications. Such loss was not due to the failure of British scientists and inventors to find new discoveries or to make radical innovations because British scientists and inventors made outstanding contribution to the development of electricity. In contrast, German and American industry exploited the generally available new scientific knowledge far more effectively than British industry by rapidly creating the institutions to identify, adopt, diffuse, and exploit available technologies (Freeman 1992).

It is clear that institutional innovations are as important as scientific discoveries in the national innovation system.

Technological information system

Patents provide information on domestic and foreign technology. Information and database on firm capabilities can help firms find joint

Table 9. Product technology capability in the metal fabrication industry

Product	Technology Capability Intervention
A. Origin Equipment Manufacturer (OEM) Machinery Parts	
1. Development	Training of research staff and IPR
B. Replacement Casting Parts for Local Mining, Cement Quarrying, and Milling Equipment	
1. Production	Training in modern foundry operations, quality control, and heat treatment technology
C. OEM Automotive Parts Casting Parts	
1. Production	Training in new technologies
2. Marketing	Marketing skills tailored to the replacement parts in the local market
D. Tool and Die for Manufacturers of Semiconductors	
1. Production	Training in the use of modern equipment and processes; adoption of standard die components
2. Procurement	Purchasing/inventory control on standard die components
3. Engineering	Training in die design capability; innovation in reconfiguring obsolete equipment
E. Appliances	
1. Production	Expansion of subcontractors with capability to supply assembler; training in production of intermediate products
2. Marketing	Promotion of exports of appliances

Source: Roble (1995).

venture partners, formulate export promotion programs, and target sectors for inward foreign investment. Permissive intellectual property regime in new and emerging industries will facilitate technology diffusion through the entry of numerous startup firms. Commitment to meeting international product quality standards (e.g., ISO 9000) facilitates both national and international trade. A common metrology and testing center is useful in providing common service facilities for calibrating machinery and testing instruments. Testing services can likewise be provided by the private sector.[5] A credible laboratory certification process helps develop the market for new and established products.

The number of patents granted to local investors stood at 888 in 1999 (from 741 in 1981). However, in 1998, only eight patents were granted. On the other hand, the number of patents granted to foreign investors was placed at 804 in 1999 (from 806 in 1981). The 1998 figure was 568. Although the number of local patents registered with the Intellectual Property Office is not impressive, access to foreign patent information will meet the objective of providing information on firm capabilities for local companies that will assist them in formulating strategies for partnership and strategic alliances with foreign firms. Sometimes the number of patents is misleading. For instance, although American universities licensed a substantial number of patents, most of the revenues generated by universities came from a relatively few non-exclusive licensed patents of a very basic nature (Hane 1999). Some argue that Japanese technological performance is overstated if patents are used in international comparisons because the Japanese have registered "more patents than others because the knowledge they seek to protect tends to be less significant technologically" (Okimoto and Saxonhouse 1987). Evidence also shows that the number of registered Japanese patents is understated because Japanese professors do not bother to register them because of lack of legal and administrative support and the financial costs involved (Hane 1999).

The legal framework for intellectual property protection has been firmed up by the passage of Republic Act No. 8293, prescribing the Intellectual Property Code and establishing the Intellectual Property Office (IPO). At the University of the Philippines, proposed guidelines governing intellectual property rights have been drafted. Various RDCs under DOST (e.g., PCHRD) have also formulated technology transfer guidelines (Ancog 2001).

Standardization in the Philippines is government-dominated. Substandard goods abound in the domestic market and the majority of export products are manufactured according to the standards and

[5] Bureau of Product Standards (BPS) has about 30 accredited testing laboratories in Metro Manila, 25 of which are privately owned (Raneses 2000).

specifications prescribed by foreign buyers. Although national standards in the Philippines are comparable with other developing countries, standards in the basic industries (machinery, electronics) are inadequate. Among the factors explaining the low stock of standards are the following: lack of information or understanding of standards, lack of competent testing facilities of international caliber, lack of competent manpower on standardization, and lack of technology guidance on quality improvement for SMEs (Raneses 2000).

Financial system

A sophisticated financial system that provides a pool of venture capital builds a strong foundation and support for the survival and growth of numerous high-technology startup companies. If the venture capital market is excessively focused on short-term results, it will not be of big help in the development of firm-level technological capability in the long run.

The U.S. experience shows that a vigorous venture capital market emerged when intellectual property protection was permissive in the computer, electronics, and biotechnology industries. But the financial market became conservative when intellectual property protection was tightened in these emerging technologies.

The contribution of the financial system to a well-functioning innovation system depends on how open bankers and investors are to the concept of lending to entrepreneurs and firms based on intangible assets with good business prospects. Intangible assets can take the following forms: discoveries of inventors, new scientific findings of scientists, and tacit knowledge and skills among managers, entrepreneurs, engineers, and workers. Currently, the banking system is collateral-intensive. Ancog (2001) and David (1999) suggest the allocation of more resources for research, development, and technology commercialization. For instance, technology generation in corn and sugar is underfunded (David 1999). In contrast, Kodama (1995) has shown that the R&D expenditures of major Japanese companies had exceeded capital investment by 1985 (Table 10).

Government

Government plays an important role in the innovation process because it directly supports research, development and the promotion of science. Government policy on taxes, tariffs, standards, and environment influences the rate and direction of innovation. But the

Table 10. R&D expenditures and capital investment in major Japanese manufacturing companies: 1985-1987

Company	R&D Expenditures (million yen) (1)	Capital Investment (million yen) (2)	R&D/Capital Ratio (1)/(2)
1. Toyota Motor	258,333	301,333	0.86
2. Hitachi	251,773	123,367	2.04
3. NEC	235,667	180,667	1.30
4. Matsushita Electric	204,647	41,971	4.88
5. Toshiba	179,133	127,433	1.41
6. Fujitsu	163,637	113,833	1.44
7. Nissan Motor	160,000	106,533	1.50
8. Honda	114,867	80,380	1.43
9. Mitsubishi Electric	113,000	77,000	1.47
10. Sony	92,978	77,968	1.19
11. Mitsubishi Heavy Industries	87,333	65,022	1.34
12. Mazda Motor	77,433	102,667	0.75
13. Nippondenso	59,860	86,233	0.69
14. Canon	59,563	53,579	1.11
15. Sharp	59,164	56,176	1.05
16. Nippon Steel	55,000	140,000	0.39
17. Fuji Photo Film	43,278	42,533	1.02
18. Sanyo Electric	41,945	56,261	0.75
19. Ricoh	36,720	26,671	1.38
20. Takeda Chemical Industries	34,900	22,440	1.56
21. Kobe Steel	34,233	71,865	0.48
22. Asahi Chemical Industries	33,833	52,033	0.65
23. Kawasaki Steel	31,267	100,133	0.31
24. Ishikawajima-Harima	31,267	12,933	2.42
25. Bridgestone	29,667	36,467	0.81

Source: Kodama (1995).

most important influence of government in the process of innovation lies in the user and procurement function of innovation, which makes a big difference on the commercial viability of new products in the market.

Government policy was blamed for the decline of the British innovation system from 1900 to 1950. Weak antitrust policy encouraged anticompetitive price and market-sharing agreements among British firms, which undercut the incentives for the pursuit of competitive advantage through innovation. Cartel agreements among small and inefficient firms were legitimized in the 1930s. And financial support for technical and managerial education at the secondary and university levels was minimal despite the need to improve the number of engineers and the quality of its training (Mowery and Rosenberg 1989). Government policy was likewise blamed for the slow institutional response and the loss in productivity leadership for Britain in new industries (e.g., electric power, synthetics, automobiles, and precision engineering) at the end of the 19th century (Freeman 1992).

In the Philippines, David (1999) has documented the weaknesses in the institutional framework of the research system in the agricultural and natural resources sectors. For instance, only 30 to 40 percent of public expenditures for these sectors have been allocated for productivity-enhancing expenditures. Cororaton (1999b) confirms the underinvestment in R&D and estimates the corresponding gap at about 0.5778 of GNP, or approximately P14.6 billion in current prices in 1997. It does not help that the Department of Agriculture (DA) is still drafting the guidelines for the commercialization of genetically modified crops. Local government units are no help either. Recently, for example, the municipal council of Ilagan, Isabela voted unanimously against a plan for Monsanto to conduct field trials for dry season Bacillus thuringiensis-injected corn (popularly known as BT corn) in this town even though Monsanto obtained a permit from the National Committee on Biosafety of the Philippines (*Manila Bulletin*, 5 January 2002).

Finally, Table 11 shows the concentration ratios, effective protection rates, and cost-price margins in selected Philippine manufacturing industries, where scientists and engineers are concentrated. Although effective protection rates have fallen substantially from 1988 (the start of the Tariff Reform Program),

Table 11. Concentration ratios, effective protection rates, and price-cost margins in selected manufacturing industries (in percent)

Industry	Concentration Ratio (1995)	Effective Protection Rate (1994)	Price Cost Margin (1995)
Petroleum Refineries	100.00	20.07	32
Professional and Scientific	99.97	1.09	24
Nonferrous Metal Products	98.57	-1.15	24
Glass and Glass Products	92.05	20.21	52
Industrial Chemicals	84.65	3.04	31
Transport Equipment	84.40	57.32	23
Iron and Steel	70.55	9.12	24
Machinery (except electrical)	79.43	0.36	28
Petroleum and Coal Products	87.40	-10.06	26
Fabricated Metal Products	74.32	28.74	28
Other Chemicals	69.09	29.14	46
Textiles	72.37	7.95	30
Food Processing	81.74	14.45	32
Food Manufacturing	77.92	50.26	41

Source: Aldaba (2000).

concentration ratios are still absolutely high in these industries (averaging 83.75%) in 1995. Concentration ratios are positively correlated with price-cost margins. The dominant market position of these industries can be explained by the lack of an effective competition policy in the Philippines. Aldaba (2000) claims this situation has led to the underinvestment in R&D by the private sector. This predicament is akin to the British situation from 1900 to 1950. While the British case led to the loss of technological leadership, the Philippine case illustrates why technological catch-up is extremely difficult.

IX

Diagnosing the Problem

The poor private sector participation in R&D is manifested by the lack of interest in availing itself of R&D-related incentives offered by the Board of Investments (BOI). Since 1991, only 11 companies availed of BOI incentives for R&D activities. Cororaton (1999a) points to the weak link between the government and the private sector in terms of R&D activities (e.g., absence of respectable databases and technology information system). Furthermore, at least 70 percent of total R&D expenditures in the Philippines is accounted by the public sector (Patalinghug 1999). The argument for incentives is that it is necessary to induce private R&D investment. The recent findings of a survey revealed that private firms preferred government incentives for infrastructure or tariff reduction to reduce the cost of doing business over government incentives for R&D (Gutierrez 2002). R&D is not an attractive undertaking in the Philippines. First, few are undertaking R&D because they lack the capability. Second, non-R&D incentives are more generous and are marked by a capital-using bias compared to the existing R&D incentives. A catch-up innovation system will address the technological capability-building needs of local firms and industries.

The private sector is reluctant to develop R&D and is incapable of doing so. The reluctance is due to the uncertainty, risk, and high cost that accompany R&D investments. The lack of capability is attributable to the limited number of technical personnel that can understand, adopt, modify, assimilate, disseminate, and improve on imported technologies. The thrust of the Philippine national innovation system must be the establishment of institutions and the promotion of institutional innovations that build the capability to monitor, choose, adopt, disseminate and modify existing stocks of knowledge. For instance, government R&D institutes do not have the flexibility, accountability, incentives, and fiscal autonomy to create opportunities for cooperative research with the private sector, or with the universities. On the other hand, the private sector must possess the willingness to respond to opportunities open to them even in an unfamiliar business requiring the use of new techniques. The private sector must share the risks and costs of undertaking R&D with the government. Economic incentives can only work under this environment.

Philippine semiconductor exports contributed only 10 to 15 percent of value-added. One explanation for this predicament is the shortsightedness of Filipino investors. Investors and financial institutions are motivated by short-term expectations. They have neither interest in nor understanding of the long-term opportunities and needs of their industries. The high cost of capital forces companies to have a short-term horizon because they fear that long-term investment opportunities threaten their survival. Are managers' short-term horizons forced on them by external conditions (e.g., the inability of the financial system to lower the cost of capital) or is it a manifestation of the managers' lack of risk-taking skills and lack of knowledge about their companies' products, markets, production processes, and opportunities? The explanation must be a combination of both. However, an innovation system that consists of a financial system with a dynamic venture capital market will provide a strong support for managers and companies that pursue long-term opportunities for their businesses.

Broader training for workers increases flexibility, improves productivity, and reduces coordination costs. However, firms are reluctant to invest in extensive training because of the mobility of workers who might bring the newly acquired skills to competitors. Labor mobility also exists in Germany, but German firms continue to invest heavily in worker training. Market failure exists because worker training benefits the whole economy, but it is not in the self-interest of individual firms to undertake the investment. The solution is for government to encourage public-private partnerships for job training. Labor-management bargaining may target on training as a major non-wage demand. But the pressure on individual firms will be difficult to resist if training is institutionalized in the tripartite bargaining among management, labor, and government. Tax benefits or tax incentives may be offered to firms investing in worker education and training. Government must also work harder to develop an environment of cooperative (rather than confrontational) labor-management relations in the country (Dertouzos et al. 1989). The change in the atmosphere requires that government seeks cooperation from other sectors (academe, labor, industry, and civil society) to achieve this goal. MNAAP can support ongoing productivity improvement programs such as labor-management councils, gain-sharing schemes, and safety/ health committees.

While the practice of lifetime employment played a crucial role in the successful management of the Japanese innovation system, the prevailing practice in the Philippines is contractual employment. Esguerra (1997) argues that hiring costs and firm-specific human capital determine a firm's decision to invest in a long-term employment relationship with its employees. The firm's dependence on nonregular workers will be greater for jobs or positions that require minimal firm-specific skills. Korea encourages firms to invest in firm-specific skills. A law enacted in 1974 made inplant training compulsory for all industrial enterprises employing 300 or more workers (Kim 1997). An effective innovation system must possess the intensity of effort and commitment to expose workers and firms to new knowledge. Firm-based training is a conscious effort to internalize new information and techniques. In other countries with weak firm training policies, strict implementation of their social and labor laws practically makes it extremely difficult to practice contractual employment. Building new skills and flexible human capital is consistent with MNAAP s goal of developing globally competitive human resources.

IX

Conclusion: Bridging the Gap

The framework of the Philippine innovation system must focus on the catch-up type. The prerequisite of this type of innovation system is the establishment of institutions and promotion of institutional innovations that build the capability to monitor, choose, adopt, disseminate, and modify existing stock of knowledge. Institutional innovation requires not only a shorter time lag from technology adoption phase to commercialization phase, but also the promotion of vigorous competition among domestic firms which cooperate in the development stage of generic technologies.

Another measure of a successful catch-up innovation system is the willingness of the private sector to respond to opportunities open to them, start an unfamiliar business, and assimilate new techniques.

A catch-up innovation system requires a significant role of government in the start-up costs (mostly buildings and equipment) of R&D institutions that are needed to make the overall system work efficiently. However, the failure of government support to technological development can be explained by government assumption of nearly all costs of the new institutions. Managers and private firms have the incentive to carry out a project even if they expect it to have no commercial use. The problem can be avoided by letting the private sector share the risks and cost with the government.

The university-industry collaboration is practically non-existent in the Philippine innovation system. Although there are some unresolved questions on this institutional set-up, the reality is that it worked effectively for U.S., Japan, and Germany during their catch-up stage. And it has been revived to work effectively for their systems at their current technology-leadership stage. Ground rules, criteria, and procedures can be developed to make universities work in close association with industry and government in addressing the competitiveness, economic growth, and sustainability goals.

The educational and technical training system must have the capability to produce a large number of quality scientists, engineers, managers, technicians, and skilled workers. This large number of people aids the diffusion, absorption, and utilization of advanced scientific and engineering knowledge in the catch-up stage of the Philippine economy. Companies must also be willing to partly bear the risks of giving a broadly designed training to workers in high-mobility markets.

Research and development institutions will be ineffective if they aim to undertake fundamental research in big science and frontier science in a country whose short-term to medium-term needs largely require routine technology assistance in improving existing operations using proven technologies; and strengthening quality, inventory, control, design, training, and marketing. Most of the existing government RDCs must expand and deliver effectively their TRC-type services for SMEs. But government must eventually phase out their involvement in technology extension institutions (TRCs) because they will just displace potential private investment that is likely to be more cost-effective due to its greater responsiveness to markets.

Testing and certification services of high caliber help develop the market for new products and services. A strong network of standard-developing bodies comprising of government, industry, and universities can be encouraged. There is also a need to institute a consistent and sustained promotion of standards as quality, productivity, and technology management tools.

Finally, government can address the ineffectual R&D incentive scheme by implementing a catch-up innovation system that addresses the technological capability-building needs of local firms and industries.[6] Public-private partnerships in job training will address the reluctance of firms to invest in extensive worker training. Building new skills and flexible human capital is consistent with MNAAP s goal of developing globally competitive human resources. MNAAP can likewise complement ongoing initiatives on productivity improvement such as labor-management councils, gain-sharing schemes, and safety-health committees.

[6] See Patalinghug (2001) for possible incentives to R&D activities.

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