1 SCIENCE, TECHNOLOGY, AND INNOVATION DISCUSSION PAPER SERIES

Review of World Bank Lending for Science and Technology, 1980–2004

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ABBREVIATIONS AND ACRONYMS

APL	Adaptable Program Lending
CAS	Chinese Academy of Sciences
CENAM	Mexican National Center for Metrology
CGIAR	Consultative Group on International Agricultural Research
CIAL	Local Agricultural Research Committee
CIAT	Centro Internacional de Agricultural Tropical
CONACYT	National Council of Science and Technology
ERC	Engineering Research Center
ESDAR	Office for Agricultural Research and Extension
FARA	Forum for Agricultural Research in Africa
FDI	foreign direct investment
GNP	gross national product
HDNED	Human Development Network for Education
IARC	International Agricultural Research Center
ICR	Implementation Completion Report
ICT	Information and Communication Technologies
IFC	International Finance Corporation
IIT	Indian Institute of Technology
IPR	Intellectual Property Rights
ISO	International Organization for Standardization
K4D	Knowledge for Development Program
KAM	Knowledge Assessment Methodology
KBSC	Korea Basic Science Center
KE	Knowledge Economy
KIET	Korean Institute of Electronics Technology
KTDC	Korea Technology Development Corporation
LIL	Learning and Innovation Loan
MAM	Marmara Research Center
MSI	Millennium Science Initiative
MSTQ	Metrology, Standards, Testing and Quality
NAIS	National Agricultural Innovation Systems
NARI	National Agricultural Research Institute
NARS	National Agricultural Research Systems
NGO	nongovernmental organization
OED	Operations Evaluation Department
PAD	Project Appraisal Document
PSR	Project Supervision Report
R&D	Research and Development
RDI	Research and Development Institutions
SAR	Staff Appraisal Report

SME	Small and Medium Enterprises
SPAAR	Special Program for African Agricultural Research
S&T	Scientific and Technological
TDR	Special Program for Research and Training in Tropical Diseases
TPE	Turkish Patent Institute
TSS	Technology Support Services
TTGV	Technology Development Foundation of Turkey
UME	National Metrology Institute
VC	Venture Capital
VET	Vocational and Technical Education
WHO	World Health Organization

INTRODUCTION

Purpose

1. This analysis measures the amount of World Bank lending to support scientific and technological (S&T) research and S&T capacity building. It devises a taxonomy and methodology for identifying such S&T projects, and differentiates these from other World Bank lending that may be more loosely related to science and technology. The analysis also identifies trends in operational support for science and technology. Trends and initial lessons were also identified in recent related Bank reviews, evaluations, and strategy papers:[1] some key tables and boxes are reproduced here with permission, particularly as annexes to this document, for further illustration and to provide concrete examples and policy/activity options for the Bank in the S&T field.

2. *Support for Science and Technology is One Part of the Bank as a Knowledge Institution*. This analysis and quantification includes only World Bank lending operations that directly supported S&T research or explicitly attempt to build S&T capacity. Supporting this capacity in client countries is one of the ways in which the World Bank has promoted greater use of knowledge for development. A number of Bank lending operations, programs, or initiatives do the same, without having a specific focus on S&T knowledge. The paper "Major Knowledge Initiatives of the World Bank Group: Relevance for World Bank Education Sector Lending and Research" (Patrinos 2001) summarizes these efforts and provides a detailed overview of the context in which this present analysis of S&T lending can be understood.

Box 1: Methodology
An initial broad list of nonagricultural projects was generated by reviewing the brief descriptions for all such projects published in the World Bank annual reports for the years 1980–2004. Information on agricultural projects was also compiled in this manner for the years 1980 and 1997–2004, and by Byerlee and Alex (1998) for the years 1981–96. Any project that might possibly have an S&T component was included in the list. Next, a number of projects were eliminated after reviewing their development objectives and main project activities as listed in project supervision reports (PSRs), staff appraisal reports (SARs), or project appraisal documents (PADs). Projects were considered major S&T projects if at least 50 percent of total project costs went toward activities defined herein as S&T components. Also, a distinction was made between agricultural and nonagricultural projects, because of the systematization of agricultural research data and the volume of lending for agricultural research activities (see annex A for details and tables with aggregated data).

THE TAXONOMY FOR IDENTIFYING S&T PROJECTS

3. *S&T Projects Seek to Build Capacity to Produce, Select, Adapt, Diffuse, and/or Use S&T Knowledge.* Projects and project components were considered S&T operations—and therefore

[1] Byerlee and Alex (1998, 2003); Goel, Koryukin, Bhatia, and Agarwal (2004); Lele (2004a, 2004b); Rygnestad, Rajalahti, and Pehu (2004); and Watson, Crawford, and Farley (2003).

included in the aggregate lending totals—if they provided funding for research or explicitly sought to increase S&T capacity.

Agricultural and Nonagricultural S&T Projects

4. S&T operations were studied as two distinct groups: *agricultural and nonagricultural S&T projects*. The rationale for this distinction include: (1) agricultural projects have been tracked and analyzed as a group for decades, and have a body of experience that relates to them specifically; (2) the development of S&T capacity for agricultural research has many characteristics that makes it unique (much crop research is local in character or confined to a given agro-ecological zone); and (3) in the wake of the green revolution, and given the universality of the need for food security, virtually all Bank clients saw agriculture and agricultural research as development issues, therefore creating a significant volume of operations in this area. This was not the case with general S&T capacity until the "Knowledge for Development" work of the late 1990s (World Bank 1999).

Agricultural and Rural Development Projects

5. These projects supported increased competitiveness and productivity of the agriculture sector through investments in adaptive and applied research, the strengthening of the National Agricultural Research Systems (NARS), and human capital formation. Agricultural research projects are, in general, comprehensive projects. Most projects were crop related, and there were few relevant projects on fisheries, livestock, and forests.

Nonagricultural Projects

6. Nonagricultural projects were classified as follows:

7. *Comprehensive S&T Development Projects*—linking supply and demand for S&T services, these projects supported activities such as matching grants for Small and Medium Enterprises (SME), fostering university and industry cooperation, and promoting intellectual property rights.

8. *Human Resource Development Projects*—including university-based research and education, polytechnic (tertiary) education, and secondary science education. University education included graduate education in general, and undergraduate education focused on S&T fields.

9. *Technology Development Projects*—including projects to restructure public Research and Development (R&D) institutes to make them more responsive to industry needs, projects to enhance technology development in industry, and projects focused on Metrology, Standards, Testing, and Quality (MSTQ) systems.

10. *Health Projects*—including support for infrastructure capacity building (laboratories upgrade/networks and human resource formation), operational research, disease surveillance, and R&D activities.

11. *Environmental Projects*—including support for quality control laboratories and capacity building at environmental protection agencies.

Projects Not Considered as S&T–Specific for the Purpose of This Review

12. More detailed descriptions and examples of these types of projects are provided below. Under the criteria utilized in this review, an SME promotion project or component, for example, was only included if it supported the development of products and processes through technology upgrading. If, on the other hand, an SME project sought to improve performance through management upgrades or by increasing access to credit, it was not included. Similarly, higher education projects or components were included only if they had a specific focus on supporting research or education in S&T-related areas, such as engineering. Projects focusing on improved access, financing or quality in higher education might have implications for S&T capacity, but these projects were not considered "explicitly" pertaining to science and technology.

13. Bank lending supports a number of operations that might qualify as S&T projects under broader definitions: projects that installed sophisticated technology "as is," for example, in distance education (for instance, global distance learning centers) or telecommunications/information and communication technology (ICT) projects. In general, projects that just acquired high-tech equipment or projects with high technology content were not included unless the building of local capacity comprised a significant portion of the project. For this analysis, such projects were not deemed to be directly related to research or building S&T capacity and hence were not included. Some of these projects may have had some impact on the clients' S&T capacity, but in a way that was very dispersed or difficult to measure. While it is worthwhile to examine the effectiveness of the Bank as a vehicle for technology transfer, this topic is outside of the scope of the analysis. Indeed, an analysis of World Bank projects that focus on transferring sophisticated or simple technology may be found in a number of other studies, including Weiss and Jequier (1984). Several other categories of projects loosely related to science and technology were also not included in this analysis, because their connection to improved S&T capacity was too indirect or because some logistical problem put them beyond the scope of this inquiry. Among these were projects or project components that supported the following:

14. *Management Training and Modernization Projects.* The provision of management training and modernization, as well as the use of existing knowledge in private sector development, can lead to organizational improvements in firms that strengthen technological capability; however, such efforts were not considered in the analysis unless the projects explicitly attempted to accelerate the rate of technological learning through direct interventions.

15. *Basic and Secondary Education Projects without Specific S&T Goals.* Improving science instruction is a stated goal of many primary and secondary education improvement projects. Normally, it is carried out as one part of an integrated package of interventions to improve the overall quality of education. It would be worthwhile to gauge the effectiveness of Bank support for science education, but such an inquiry was beyond the scope of this paper. Such an analysis was done a decade ago by Ware, el Hage, Rinaldi, and Thulstrup (1992) and should be updated.

However, basic and secondary education projects that promoted improved science and technology were not identified or included here unless they made provisions to improve science education specifically.

16. *Vocational and Technical Education (VET) Projects.* Only projects focusing on polytechnic education at the tertiary level were included. VET projects were not included because polytechnic-level skills are normally more advanced than those of secondary-level vocational institutes. Again, one could argue that enhanced vocational and technical skills add to a country's S&T capacity, and these should be analyzed. However, for logistical reasons, these were deemed outside the scope of the paper.

17. *Higher Education Projects.* Many general university reform projects create conditions for improved S&T capacity; however, if improvement of scientific and technological research and capacity was not specified as a principal goal of the project, it was not included.

18. *Agricultural Extension Services Projects.* These projects are often popular vehicles for the diffusion of relevant research outcomes and products; however, because of difficulties in disaggregating their S&T content, they were not included in the list unless supporting research was an explicit project goal.

19. In light of these parameters, this analysis depicts the Bank's overall support for science and technology as narrower than it in fact is. Thus, the numbers presented in this report should be considered conservative estimates of the Bank's overall effort to promote science and technology. More methodological details, as well as aggregate project figures are provided in box 1 and annex A.

GLOBAL CHARACTERISTICS OF BANK LENDING FOR S&T PROJECTS

Main Findings

20. *Between 1980 and 2004, the World Bank lent $8.6 billion dollars*[2] *to directly support S&T activities through 647 projects.* Annually, average lending for science and technology totaled $343 million.

21. *Of overall Bank lending, 1 of every 9 projects provides some support to S&T capacity building, but only 1 in about 50 projects is principally concerned with improving science and technology.* Although 647 projects over the past 25 years provided some support for science and technology, only 119 of the World Bank's 6,059 projects were dedicated primarily to promoting science and technology or contained a significant S&T capacity building component.

22. *The World Bank sponsored, on average, 26 S&T projects per year.* Five projects a year provided major support for science and technology (50 percent or more of total project costs) and

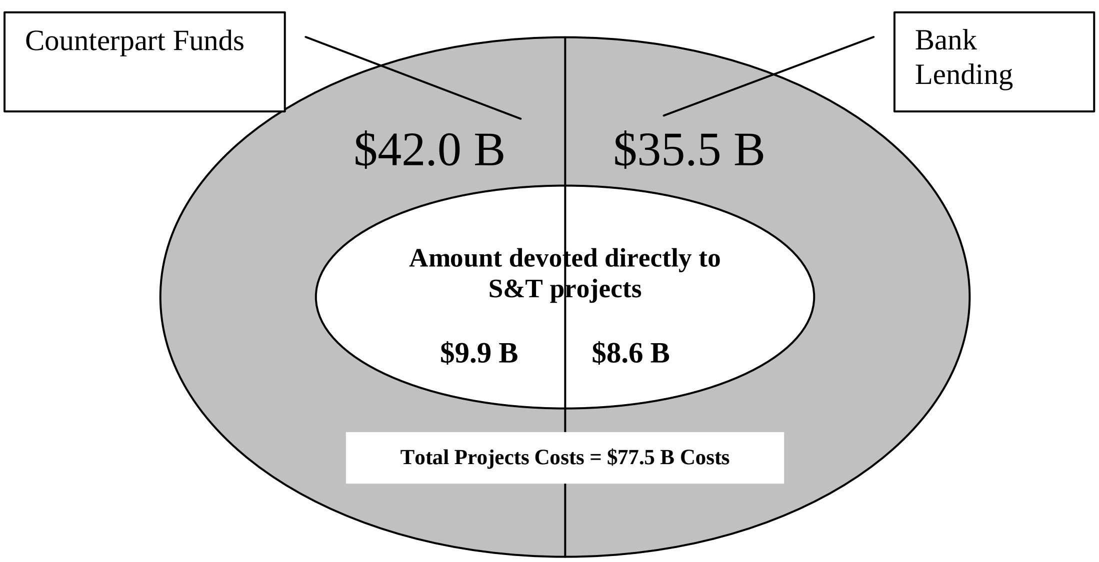
[2] All dollars are U.S. dollars unless otherwise indicated.

21 projects a year provided minor support for science and technology (less than 50 percent of total project costs).

23. *The Agriculture and Rural Development Sector provided more support for S&T projects than all other sectors combined.* The agriculture sector accounts for about 42 percent of all major S&T projects, the remainder consisting of the other sectors combined, but predominantly education and industry. Agriculture also accounts for the overwhelming majority of projects that provided minor support to science and technology (more than 400 of the 528 minor projects were in agriculture). Additionally, S&T Support to Agriculture was geographically dispersed and covered large and small, low- and middle-income countries.

24. *Most major support for S&T projects (outside of agriculture) went to a handful of large, middle-income countries.* More than 50 percent of the major S&T loans (nonagricultural) went to only 7 countries, and about three-quarters of the loans were taken by 14 countries. In terms of regional distribution, East Asia received about 40 percent of all major S&T loans during the review period. The next most frequent S&T borrower, Latin America, took out about 20 percent of the loans.

Figure 1: Bank/Counterpart Breakdown for S&T Projects, FY80–2004



Source: Own elaboration (Annex A).
Note: Shaded area = Total Bank Lending ($35.5 B) + Counterpart funds ($42.0 B) for S&T projects minus the $18.5 B directly devoted to S&T activities (Total value of shaded area = $59.0 B).

S&T Lending as a Percent of Overall Bank Lending

25. The 647 projects that supported science and technology represent 11 percent of all Bank projects (6,059) for the period. The $8.6 billion of direct lending support for S&T activities represents only 24 percent of the total World Bank lending ($35.5 billion) to these projects. The

remaining 76 percent was used for project activities that did not directly support science and technology. When counterpart funds are included, the 647 projects amounted to $77.5 billion in total project costs, $18.5 billion of which (also 24 percent) were dedicated exclusively to activities that support science and technology. The $8.6 billion in Bank lending, then, can be considered to have leveraged an additional $9.9 in counterpart country investments in S&T capacity building.

Major and Minor S&T Projects

26. *Support was divided between Major and Minor S&T projects.* Of the 647 projects, 528 devoted less than 50 percent of total project costs to directly support S&T activities. Many of these minor projects were in agriculture, in which a smaller portion of the overall project cost went to directly support an S&T component relevant to agriculture. Of the 647 projects, 119 were considered "major S&T projects" that devoted 50 percent or more of total project costs directly to research and S&T capacity building.

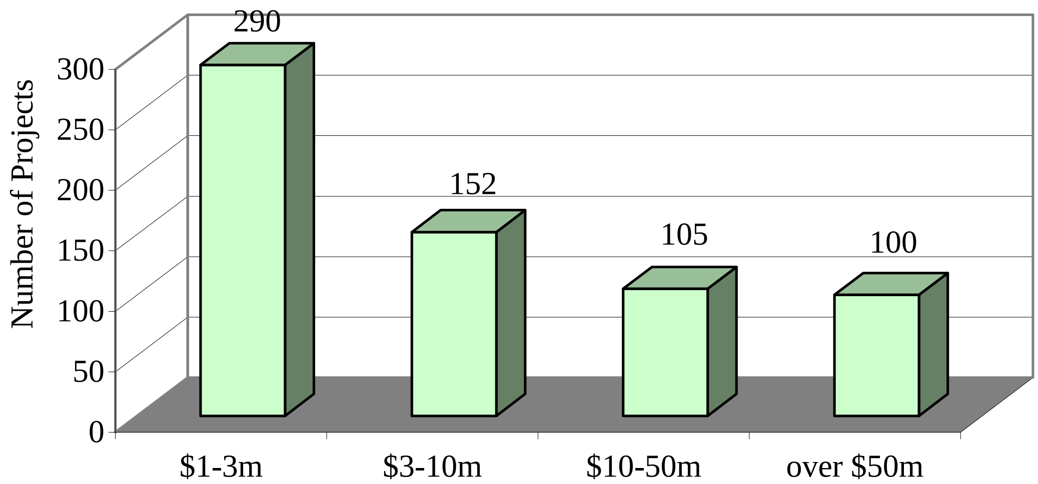
Table 1: Bank Lending for Projects Involving Science and Technology by Intensity and Support(billions of dollars), FY80-2004

Type of Project	Number of Projects	Total Lent	Total Project Costs	Total Amount Devoted to S&T
Total	647	$35.5 B	$77.5 B	$18.5 B
Major S&T Projects	**119**	**$7.6 B**	**$15.8 B**	**$13.8 B**
Minor S&T Projects	**528**	**$27.9 B**	**$61.7 B**	**$4.7 B**

Source: Own elaboration (Annex A).

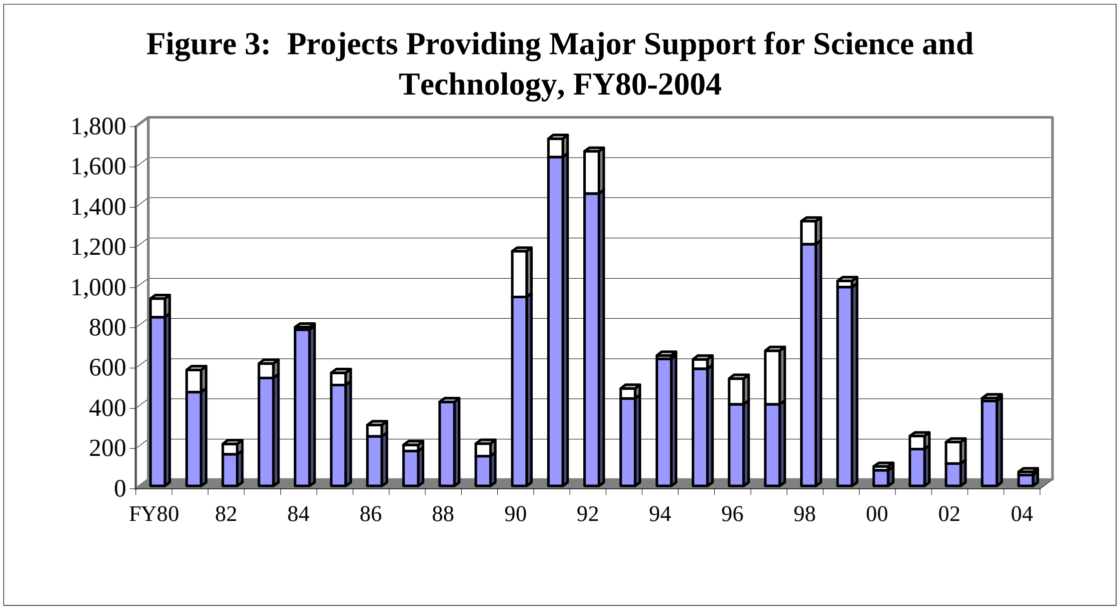
27. Figure 2 depicts the level of support for S&T projects between 1980 and 2004, by funding amount. As the figure shows, 290 projects used less than $3 million for science and technology; 152 projects used between $3 million and $10 million; 105 projects used between $10 million and $50 million; and 100 projects used more than $50 million in funding to build S&T capacity or strengthen scientific research.

Figure 2: Projects Categorized by Amount Devoted Directly to Science and Technology between FY80-2004



Source: Own elaboration (Annex A).

28. Figure 3 provides annual data for the number of major projects for S&T capacity building and research. On average, 88 percent of total project costs for these 119 major projects were S&T specific. The profile of project amounts devoted to science and technology (given by the dark portion of the columns) pretty well mirrors that of figure 5 corresponding to total costs of agricultural research and extension projects. This is consistent with the predominance of S&T investments in agricultural projects, which showed important peaks around FY91/92 and FY98/99 (see the lower graph in figure 5), with the lowest lending levels in recent times around FY88, and later since FY2000 (see discussion in the section "Lending and Policy Trends" starting with paragraph 42). Furthermore, the peaks in figure 3 show that few large or larger projects can make a substantial difference in a given year's lending for S&T activities. Nine major projects were approved in FY90 and another nine projects in FY91, as opposed to an average of four projects per year between FY80 and FY89. In FY92, seven major projects were approved, with an average cost of $238 million (compared with the average of $132 million per project for the 25 years covered in this review). In FY98 and FY99, the determinant factor was larger projects (averaging $263 million and $170 million per project, respectively) because the number of major projects approved per year remained constant at five from FY93 to FY01, with the exception of FY99, with six projects approved (see also annex A, table 2).

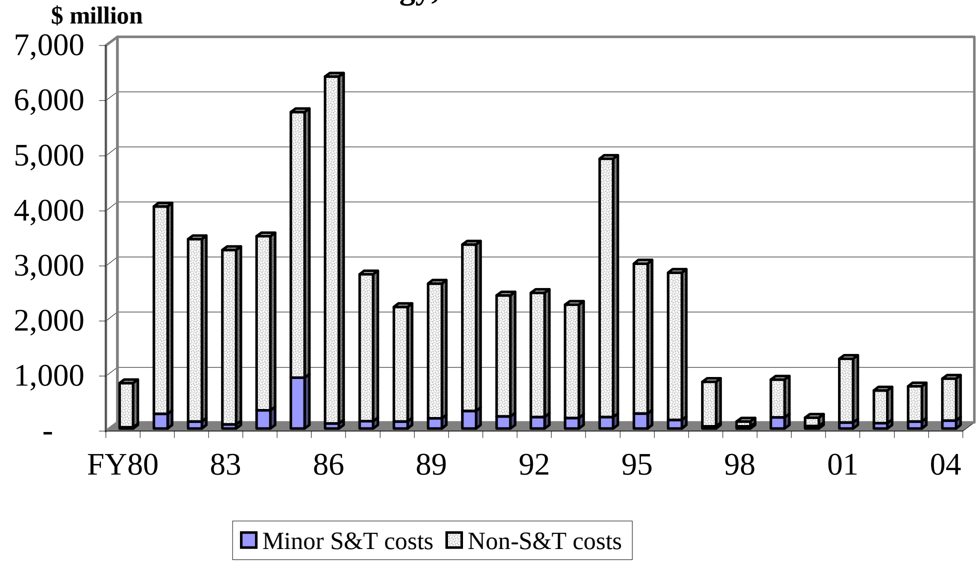


Source: Own elaboration (Annex A).

29. Figure 4 provides annual data for minor projects supporting S&T capacity building and research. On average, only 8 percent of total project costs for these 528 minor projects were S&T specific. In this case, the profile of project amounts mirrors the profile corresponding to all agricultural projects in figure 5 (upper graph), which shows a general decline since the late 1980s.

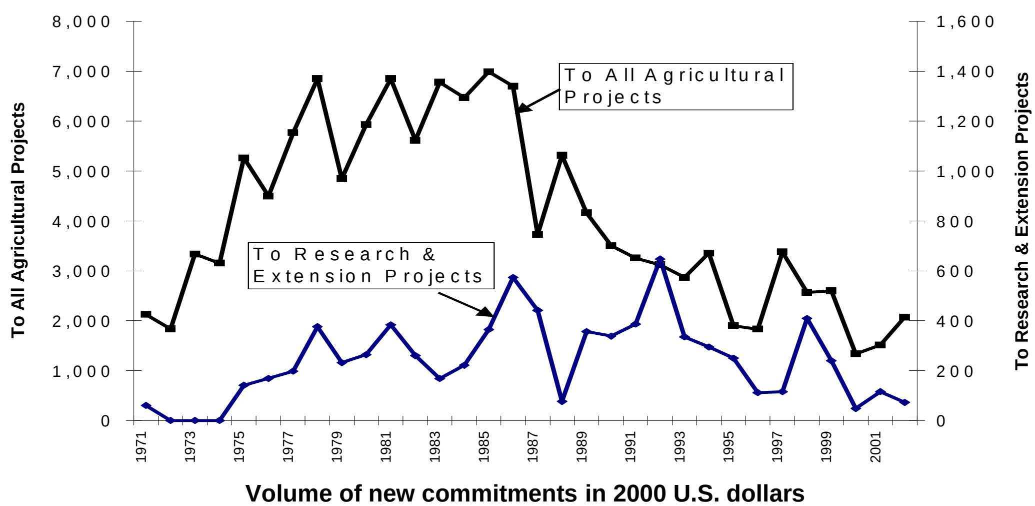
30. Thus, a preliminary conclusion is that lending to science and technology in the last 5 years has declined significantly with respect to the previous 20 years. As shown in figure 5, agricultural projects in general, and agricultural research projects in particular, have been declining in number, and apparently in amount since the 1990s. For instance, there were no agricultural projects with more than $10 million in S&T expenditures in FY02 and FY03. Also, in the last five years, there were very few major nonagricultural projects from "the big six" borrowers (see paragraph 34): only India had one large project (technical/engineering education, totaling $314 million), and two medium-size projects; while Brazil had two health projects (with S&T components of $20 million and $50 million, respectively). The prospects for FY05 show an increase with respect to FY04; however it is too early to speculate with the possibility of a considerable reversal of observed trends (see paragraph 49), which would be desirable, given that not only continued investment in science and technology are needed for capacity building but also for maintaining a country's competitiveness.

Figure 4: Projects Providing Minor Support for Science and Technology, FY80-2004



Source: Own elaboration (Annex A).

Figure 5: Bank Lending to Agriculture Declined Dramatically in the 1990s



Source: OED data, reproduced from Lele 2004.

MAIN CHARACTERISTICS OF NONAGRICULTURAL S&T LENDING

Regional Distribution of Nonagricultural S&T Projects

31. The analysis of the regional distribution of S&T projects reveals a heavy bias toward the East Asia region, which had 29 of the 69 major nonagricultural projects. Latin America had the second largest amount with 15 projects. The South Asian region had nine projects, Europe and Central Asia had eight projects, and Africa and the Middle East each had four projects during the time period. Nonetheless, while regional distribution is still skewed toward East Asia, it is becoming less so than it was during the preceding decades, when close to four-fifths of S&T-related higher education lending and two-thirds of S&T-related industry lending took place in that region alone. Also to take into account, no new major nonagricultural projects were approved for countries in the East Asia region during the last five years.

Sequence of Lending

32. *Sequential, Simultaneous, and Program Lending in Individual Countries.* Forty of the 69 nonagricultural S&T loans were made to only seven countries. The Republic of Korea was far and away the largest borrower of S&T funds. Its 12 S&T loans from 1980 to 1997 are double the number of projects in China (the second-most active borrower for nonagricultural S&T projects). India, Indonesia, Brazil, Chile, and Mexico were also large borrowers for science and technology, with six, five, four, four, and three projects, respectively, as shown in table 2.

Table 2: Distribution of Major Nonagricultural Projects

Country		Number of Nonagricultural Loans
TOTAL		**69**
Korea, Rep. of	40 of the 69 loans were made to 7 countries	**12**
China		**6**
India		**6**
Indonesia		**5**
Brazil		**4**
Chile		**4**
Mexico		**3**
Bangladesh	54 of the 69 loans were made to 14 countries	**2**
Egypt, Arab Rep. of		**2**
Mauritius		**2**
Portugal		**2**
Philippines		**2**
Thailand		**2**
Turkey		**2**
Others	15 countries had 1 loan each	**15**

Source: Own elaboration (Annex A).

33. Much of the Bank's S&T support for Korea has been sequential, with a second loan of similar nature made to the same implementing agency as an extension of the previous program

(see annex B, box B1 for project descriptions). At one point, three S&T loans were made to Korea in consecutive years and with large overlaps in their implementation periods. Similarly, in Indonesia, a loan in 1983 followed up an initial loan in 1979; a second loan in 1991 addressed science and technology more specifically than its 1988 predecessor; and a 1990 professional human resource development loan with a significant S&T component preceded yet another loan in 1995. This continuity also existed in Brazil and India (see annex B, box B4 for descriptions of projects in India). By contrast, China (annex B, box B2) and Mexico (annex B, box B3) appear to be supporting a variety of diverse objectives within the S&T sector, maintaining active S&T portfolios with loans for human resource development, research institutes, environmental concerns, and technology and industrial development. The question of the relative impact of the simultaneous versus sequential approaches bears further investigation.

Country Size and Size of the Scientific Community

34. With the exception of Chile, the six most active borrowers for science and technology (Korea, China, Brazil, Indonesia, India, and Mexico) are all large population countries. Together they account for 45 percent of the world's population and 55 percent of the population of the developing world. Korea, however, the most active borrower has by far the smallest population of these six countries. Its 48 million inhabitants equal less than half of the population of the next smallest country in this group. The volume of lending to these six major borrowers included $4.18 billion of the $5.92 billion total lending for the 69 major nonagricultural S&T projects. The average loan size for these countries was $110 million. The average loan size for the 15 countries that borrowed once was $42.2 million. These countries have, on average, much smaller populations. The figures seem to lend support to the idea that countries with large populations are also concerned with building and maintaining a critical mass of researchers and S&T infrastructure. However, the correlation does not indicate the direction of the causality. That is, we do not know whether China, for example, borrowed for science and technology because of a perceived need to reach "critical mass" in its S&T systems, or rather, because a critical mass had already evolved before Bank involvement and subsequently became the target of project support.

35. *Scientific Capacity in S&T Borrower Countries.* Of the top 14 borrowers for science and technology, Korea was both the largest borrower and the most scientifically advanced country, according to a taxonomy of S&T capacity devised by RAND Corporation for a study in 2000.[3] Although there may have been changes in the last years as countries reap the benefits of past investments, it is worthwhile to review this categorization. Korea was the only S&T borrower rated as a "Scientifically Advanced Country" by this study. The remaining countries fall into three other categories. The "Scientifically Proficient Countries" are those defined by a dynamic

[3] The taxonomy for these groupings was developed by the RAND Corporation's Science and Technology Policy Institute, as part of a background study on S&T collaboration between the developed and developing worlds. In this study, 150 countries were ranked according to a weighted composite index, which considers per capita gross national product (GNP) (as a proxy for infrastructure), number of scientists and engineers per million people (human capital), number of S&T journal articles and patents by citizens (S&T outputs), percentage of GNP spent on research and development (R&D) (input into Science and Technology); number of universities and research institutions per million people (S&T infrastructure), and number of students studying in the United States who chose not to return home at the conclusion of studies (contact with external knowledge sources).

S&T community, some world-class innovative firms, and a critical mass of world-class talent in some research disciplines. The proficient countries include China, Brazil, and India. A middle group, referred to as the "Scientifically Developing Countries," contains those countries with some pockets of vibrant research and a few firms involved in the commercialization of knowledge. Among these countries are Indonesia, Mexico, Chile, Argentina, Egypt, Mauritius, and Turkey. The final category of "Scientifically Lagging Countries" includes those countries in which S&T communities are small and fragile (or, in some cases, nonexistent), and firms show almost no capability to use S&T knowledge. Only two of the World Bank's 14 repeat S&T borrowers—the Philippines and Thailand—were rated in the lagging category.

36. According to the RAND study, of the 15 one-time S&T borrowers, 10 are categorized as "Scientifically Lagging Countries." This correlation suggests that the larger, repeat borrowers have improved their scientific capacity through greater concern for and attention to science and technology, which encouraged the commission of World Bank S&T-focused projects. Alternatively, the correlation could suggest that scientifically advanced countries maintain larger research communities and are more likely to seek World Bank assistance in further improving these systems. The reality probably lies somewhere in between.

MAIN CHARACTERISTICS OF AGRICULTURAL S&T LENDING

37. *$5 Billion in Lending to Science and Technology in Agricultural Research.* A total of 471 S&T projects in the agricultural sector were supported by the World Bank between 1980 and 2004, the majority of which were minor projects. Forty-two percent of all major S&T projects (50 projects total) were also in agriculture; thus, the Bank supports more projects in this sector than in all others combined, making it the single largest donor for both the agricultural sector and the agricultural research subsector. For an in-depth qualitative review of Bank S&T agricultural lending, please refer to Byerlee and Alex (1998) whose study on the issue informed most of this part of the analysis.

38. S&T projects in the agricultural sector have a variety of subsector foci, including research, education and extension, commodities, irrigation, credit and agribusiness, adjustment, and reform. Within the subsector of agricultural research, projects may be categorized according to the level of research sponsored as part of the effort to build S&T capacity. According to this division, project categories include large projects dominated by research-building initiatives, large projects with little emphasis on research, and small projects with either a large or small research focus. Examples from these categories are provided.

Types and Examples of Reviewed Agricultural Projects

39. *Major Agricultural Projects Focusing Principally on Research.* One of a number of major agricultural projects that focused principally on research as a means to build S&T capacity was Kenya's 1997 *National Agricultural Research Project.* The project cost $179.9 million, $80.8 million of which was associated specifically with the research component. The purpose of the project was to raise Kenyan agricultural productivity by creating a research institute focused on adaptive research and technology dissemination.

40. *Major Agricultural Projects Including a Smaller Research Component.* A major agricultural S&T project that included a smaller research component was the 1980 Côte d'Ivoire *North-East Savannah Rural Development Project*. Only $4.2 million of the $21 million in project costs were associated with funding research in this project, which aimed to pilot a rain-fed irrigation scheme among other rural development objectives.

41. *Minor Agricultural Projects.* Minor agricultural projects varied greatly, both by the extent to which they prioritized research and by the degree to which they focused on specific crops or types of technology. Examples of minor agricultural projects include Guinea's 1988 *National Seeds Project* ($10.6 million in costs, $1.7 million toward research) and Barbados' 1987 *Agricultural Development Rehabilitation Project* ($5.8 million in costs, $0.2 million toward research).

Lending and Policy Trends

42. Lending and policy toward agricultural research have been thoroughly reviewed. Several patterns and trends are worth noting:

43. Regionally, Sub-Saharan Africa receives the largest share of agricultural research lending, with this share growing in recent years (it accounted for 50 percent from 1993–96). This share may mitigate the relative paucity of support for other types of research lending to Africa and should be taken into consideration in formulating any S&T support strategy for the region.

44. The Bank's commitment to NARS has been steady and long term; many countries have had sequential NARS support projects over periods of up to 20 years.

45. The Bank has made a strong and substantial commitment to support International Agricultural Research Centers (IARCs) through, among other things, its role as a sponsor of and investor in the Consultative Group on International Agricultural Research (CGIAR) to which it donates roughly $50 million per year.

46. The Bank has played an important role in donor coordination. It has helped create such programs and facilities as the Special Program for African Agricultural Research (SPAAR) and the Office for Agricultural Research and Extension (ESDAR), a multidonor forum.

47. Research on natural resources management issues and related environmental concerns is increasingly seen as an integral part of sustainable agricultural policies and strategies.

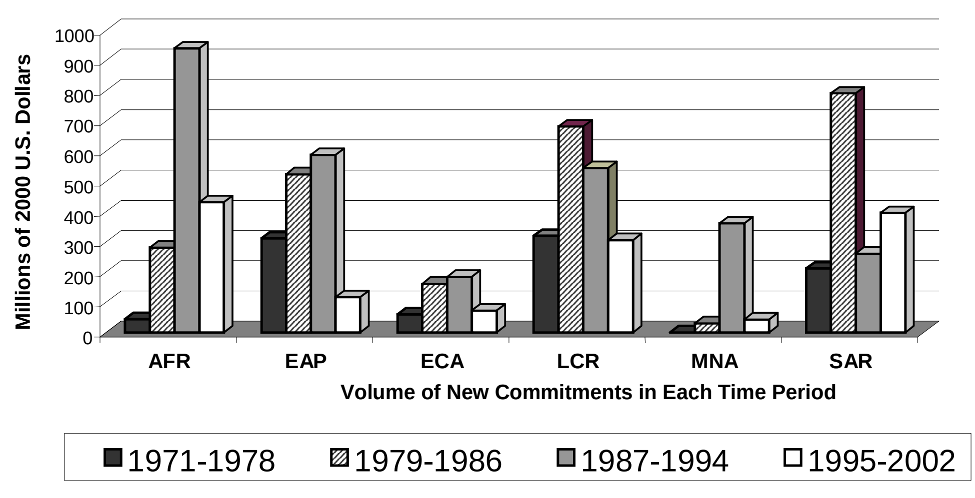
48. Despite the leadership shown by the World Bank in the agricultural sector, the total number of general agricultural projects and, to a lesser extent, research and extension projects has "dramatically" declined in the 1990s, as indicated by Lele (2004a) (figure 5). Such a decline encompassed all regions but South Asia, which is still well below the level reached during the 1980s (figure 6). A 2004 Operations Evaluation Department (OED) Evaluation points out that reasons for the decline include the lack of commitment from client countries for needed reforms in public research and poor performing loans.

49. A recent review of the rural portfolio (Rygnestad, Rajalahti, and Pehu 2004) found that there was an increase in lending for agricultural research and extension in FY04 ($230 million) compared with FY02 ($160 million) and FY03 ($118 million), projecting a twofold increase from FY04 to FY05 ($483 million). This projected increase is mainly because of a few large projects in China, India, and Tanzania. The sensibility of total lending in science and technology with respect to single large projects is much higher for nonagricultural projects, for which lending is projected to be higher than $250 million in FY05 (compared with $41 million in FY04 and $353 million in FY03) mainly because of one large project in Mexico.

Outcomes and Impacts of Agricultural S&T Projects

50. A previous OED report (World Bank 1996) evaluated the Bank's record of lending across the agricultural sector. Although the report cited significant advances made in the sector as a result of Bank work, it also noted "serious deficiencies" in sustaining research institutions and in establishing institutional capacity in research planning, priority setting, and evaluation. The review also described the vulnerability of funding to research in NARS and recommended the wider use of economic analysis to inform lending decisions and improve research efficiency (Byerlee and Alex 1998).

Figure 6: World Bank Lending to Agricultural Research and Extension, 1971–2002



Source: Reproduced from Lele 2004.
Note: AFR = Africa; EAP = East Asia and the Pacific; ECA = Europe and Central Asia; LCR = Latin America and the Caribbean; MNA = Middle East and North Africa; SAR = South Asia.

51. Despite its shortcomings in the sector, according to Byerlee and Alex (1998), the Bank successfully incorporated lessons from past experience in S&T lending in agriculture, which have led to changes in lending practices, including a notable shift in priorities after 1993 toward

management and policy competence, incentive systems, and accountability. This shift could be described as the adoption of a "quality agenda" that emphasizes the following: (1) merit and scientific rigor through the use of competitive funding, external reviews, and increased institutional links; (2) sustainability of funding through a variety of mechanisms, including public-private interaction, cost-recovery, endowed research foundations, and farmer financing; (3) more recognition of and support for human resources training, especially as conducted at universities;[4] (4) continuing efforts to reform National Agricultural Research Institutes (NARIs) and the policies that affect them; and (5) increasing knowledge-intensive agriculture through links to basic research and the international knowledge base.

52. Table 3 provides data regarding the changing foci of agricultural projects between 1990 and 1998. The table reveals such trends as increased emphasis on institutional pluralism, greater promotion of private-public interaction in R&D, and a surge in the number of projects promoting the involvement of farmers in research governance.

53. Annex C includes tables and boxes reproduced from Byerlee and Alex (2003) measuring and exemplifying the impact of agricultural research on poverty reduction, including estimated rates of return to agricultural research, distribution of benefits of cassava research in Nigeria, eradication of childhood blindness in Africa, and farmer-run research experiences. Byerlee and Alex (2003) propose the following steps to enhance the already high poverty reduction impacts of investments in agricultural research: (1) analyze the nature and causes of poverty; (2) establish a broad strategy for research investments; (3) set specific priorities for investments; (4) strengthen the institutional base for research (relying on private sector research, contractual and competitive mechanisms, financial sustainability, decentralization, and capacity building of producer organizations); (5) promote inclusive participation by the poor (participatory research); (6) promote uptake of research findings by the poor; and (7) implement monitoring and evaluation systems to measure impacts.

Table 3: Trends in Institutional Issues Emphasized in Agricultural Research Projects

Issue	Percent of Projects 1990–93	Percent of Projects 1993–99
Emphasis on institutional pluralism	50	86
Promotion of private-public interaction in R&D	12	71
Support of new funding sources	6	87
Support for competitive funding	12	86
Support for downsizing and consolidation	25	57
Involvement of farmers in research governance	38	87
Development of master plans for NARS	50	14
Emphasis on institutional pluralism	50	86

Source: Table 4.4 from Byerlee and Alex (1998).
Note: R&D = research and development; NARS = National Agricultural Research Systems.

[4] Page 63 of Byerlee and Alex notes that Bank-supported agriculture R&D projects should pay more attention to general issues of university quality and improvement, as a means to strengthening NARS. This is a potentially fruitful area of cooperation between staff in the agriculture and human developments networks.

FURTHER ANALYSIS OF NONAGRICULTURAL PROJECTS

54. *The majority of nonagricultural S&T projects have multiple components and diverse development objectives.* On average, the Bank supported three major nonagricultural S&T projects per year, representing only 1.2 percent of all World Bank projects. The largest loan given to a nonagricultural S&T project was $307.1 million (India's 1991 Second Technician Education project) and the smallest was $3.5 million (the Laos People's Democratic Republic's 1989 National Polytechnic Institute project).

55. The nonagricultural projects reviewed had multiple components and objectives, regardless of whether they provided major or minor support for science and technology. Some projects represented broad attempts to intervene throughout an entire sector (for example, in universities, research institutes, and research funding organizations), while others focused on only one S&T part of a specific sector (for example, secondary science education). The activities undertaken in these projects ranged from metrology to environmental research to basic science education; however, most projects primarily focused on human resource or technology development. The remaining projects revolved around sectoral concerns in such areas as energy, health, and the environment. For these reasons, the projects do not fall neatly into categories. A brief review of the types of interventions within these varied project categories may be useful in identifying and evaluating the nature of Bank involvement in science and technology.

Comprehensive S&T Development Projects

56. A number of projects devoted resources to increase the capacity of researchers to produce scientific knowledge and of firms to incorporate it into production. These projects often addressed both the university-based research systems and the technology-using private sector, and included activities such as the following: providing matching grants to SMEs, fostering university and industry cooperation, and promoting intellectual property rights enforcement. Several of these projects were in Latin America, including three Brazilian projects: *Science and Technology Reform Support* (1985), *Science Research and Training* (1991), and *Science and Technology* (1998); and two Mexican projects: the *Knowledge and Innovation Project* (1998) and *Science and Technology Infrastructure* (1992). Comprehensive projects in East Asia include China's *Key Studies Development Project* (1991) and Korea's *Program for Science and Technology Education* (1984). In all of these projects, lending was intended to be part of an overall sectoral reform effort. Mexico's *Knowledge and Innovation Project*, for instance, devoted approximately $265 million to research projects vetted under peer review procedures. The consolidation and expansion of peer reviews and competitive funding are considered critical means to improve the performance of science and technology in client countries.

Human Resource Development Projects

57. The majority of nonagricultural S&T projects sought or seeks to increase S&T capacity primarily by improving training systems in tertiary and secondary education. It has been common for these projects to finance the provision of S&T infrastructure, and the upgrading of laboratory equipment, in some cases accompanied by sector wide or institutional-level reform, such as improved peer-review allocation procedures.

58. *University-based Research and Education.* Of the S&T projects focused on human resources development, most occurred within the university system. Virtually all stated their development objective to be some variation of the principle goal of improving the quality and relevance of research or research and education programs. However, two distinct approaches seem to have been used for pursuing these objectives. One set of these projects supported S&T education and research by establishing or supporting competitive, performance-based funding, with improved peer-review allocation procedures. Such projects include Chile's 1999 *Millennium Science Initiative Project* and Argentina's 1996 *Higher Education Reform Project*.

59. The second set of projects pursued the same general goal of providing S&T education support, but did so without a focus on explicitly performance-based funding procedures. These projects often financed institutional support for research infrastructure, albeit without clearly redesigning mechanisms for allocating the support. Such projects ranged from the basic provision of laboratory or other science equipment and libraries and reform of curricula to staff and researcher development through overseas fellowships and more autonomous university management. Collaborations among universities (local and foreign) and research institutes, and links with industry, were components built into many of these projects, reflecting the necessity of knowledge-sharing as a basis for knowledge creation. Such projects include China's 1999 *Higher Education Reform Project* and Kenya's 1992 *Universities Investment Project.*

60. *Polytechnic and Secondary Science Education Focused.* Two other significant human resource project categories are those of polytechnic education and secondary science education. Polytechnic education projects typically involved providing some combination of specialized equipment or facilities (such as dormitories, classrooms, laboratories, and so on); new programs or schools; teacher training (through workshops, seminars, fellowships); curriculum development; and management planning (for example, *Mauritius: Higher and Technical Education Project,* 1995; *Malaysia: Polytechnic Development Project,* 1993; and *Tunisia: Higher Education Restructuring Project,* 1992). Secondary education–focused projects sought or seek to improve the quality of secondary-level science instruction. In the case of the *Korea: Science Education and Library Computerization Project* (1992), this was done by creating joint science centers to be used by both higher and secondary institutions, and by linking the libraries of more than three dozens institutions of higher learning. By contrast, the *Thailand: Secondary Education Quality Improvement Project* (1996) focused on improving the capacity of science teachers and upgrading the laboratories at teacher training institutes.

Technology Development–Focused Projects

61. Three categories of nonagricultural technology development projects bear description:

62. *Projects to Restructure Public R&D Institutes to Make Them More Responsive to Industry Needs*. In China, for example, the *Technology Development Project* (1995) assisted in the privatization of research institutes through a program that helped them convert to private, for-profit Engineering Research Centers (ERCs). Like the ERCs in the United States, these institutes had a "sunset clause," that is, a predetermined time period in which they would have to become commercially viable and self-sustaining or disappear.

63. *Projects to Enhance the Level of Technology Development in Industry*. The main focus of the *Indonesia: Technology Development Project* (1996), for example, was to provide technology services to firms, especially SMEs.

64. *Projects Focused on Metrology, Standards, Testing, and Quality*. A few projects were principally concerned with MSTQ, while several others had subcomponents devoted to it, such as *Mauritius: Technical Assistance to Enhance Competitiveness Project* (1994) that supported the creation of a national quality system, while helping to develop an MSTQ accreditation council and upgrade a variety of technical services related to metrology, testing, and dissemination of standards.

Health Projects

65. Between 1980 and 2004, 19 projects in the health sector used Bank support for S&T capacity building and research, ranging from less than $1 million (a public hospital modernization project in Korea) to $104 million (a $323 million project on rural health and medical education in China). While Bank S&T-focused health projects were relatively uncommon, those that existed were diverse.

66. One successful project was the *Brazil: Disease Surveillance and Control Project* (1999), which sought to strengthen the national disease surveillance and control system, requiring infrastructure support for a network of laboratories, a data management and communications system, and the training of management and technical staff. The system was designed to collect and publish health-related information, including incidence of disease and rates of mortality. Studies and research in epidemiological and environmental surveillance were also supported.

Environment-Focused Projects

67. Two projects addressed R&D and technology policy concerns within the context of environmental issues. The *China: Environmental Technical Assistance Project* sought to increase China's ability to understand and manage environmental problems via targeted Bank support to the Chinese Academy of Sciences (CAS) and the National Environmental Protection Agency. The *Korea: Environmental Technology Development Project* provided overseas training, visiting experts, equipment, and library materials to several research institutes to "orient their R&D activities increasingly towards environmental concerns." Also relevant, an environmental management and cartography project in República Bolivariana de Venezuela contained about 25 percent S&T-related expenditures.

Other Sector-Specific S&T Projects

68. The Bank conducted few nonagricultural S&T projects outside of the education, health, and environment sectors. Two water projects contained significant S&T components, although these focused mainly on technology and knowledge transfer. Additionally, a small handful of minor S&T projects (less than 4 percent) spanned the transportation sector (six projects) and the energy sector (one project).

Outcomes and Impacts of Nonagricultural S&T Projects

69. The Implementation Completion Report (ICR) for the *Mexico*: *Science and Technology Infrastructure Project* (1992) gave greatest consideration to the project's contribution to the overall S&T sector, and found it to have been helpful in "limiting the damage" to the research community during the 1994 and 1995 financial crises. Following the completion of the project, Mexican institutions for science and technology were stronger and more capable of promoting the long-term growth of scientific research, but the financing of research remained vulnerable. Positive impacts were attributed to improved transparency and competition through the institutionalization of peer review, provision of infrastructure, and services such as MSTQ. However, the project was faulted for its overemphasis on supply at the expense of a strategic focus on demand for S&T services. According to its ICR, the *Philippines: Engineering and Science Education Project* (1992) was found to have improved the conditions for scientific training and the supply of qualified individuals. It also instituted mechanisms for quality assurance in research and training, and greatly improved the flow of scientific information throughout the country's university system. The report recommended, however, a greater degree of involvement for the private sector. The ICR for the *China: Regional Cement Industries Project* (1992) recognized a reasonably successful privatization and technological upgrading of public enterprises, but it was ambiguous regarding the success of improved R&D capacity. The report acknowledged that both facilities and human capital had been improved but that delays in implementation had made progress unsatisfactory.

70. The ICRs from the three Korean projects that closed in 1998 all stated that the projects met their objectives, yet they also cited the inadequacy of project indicators. All three acknowledged increased scientific capacity because of increased provision of laboratories and equipment as well as improvements in efficiency and utilization of equipment. Comments on sustainability were limited to the condition of the equipment purchased. The Science Education and Computerization Project cited an 18.5 percent increase in employment for university graduates, but it did not specify whether this increase was attributable to the project. There was no mention of complementarities among the objectives of the three Korean projects, or to a larger S&T development vision, in any of the reports.

SPECIAL WORLD BANK S&T INITIATIVES

Millennium Science Initiative

71. Since 1999, through the Millennium Science Initiative (MSI), the Bank has begun to stimulate greater operational collaboration with client countries for the improvement of S&T capacity building and research. The MSI is a group of projects, partially funded by World Bank loans, which support high-level S&T research. By creating funding mechanisms that provide competitive grant support to individuals, conducting research of the highest possible quality and relevance to their societies, and maximizing training opportunities for aspiring young scientists and researchers, the MSI seeks to make long-term contributions to the building of dynamic S&T systems within developing countries. To date, five Bank clients are participating in the MSI,

with discussions under way for a number of others to participate as well (box 2). Thus, the MSI initiative constitutes an explicit attempt to encourage borrowers to use the Bank as a partner to improve S&T capacity.

Box 2: The Millennium Science Initiative: Can support to Centers of Excellence be a catalyst for reforming public support of science and technology?

In 1998, the Bank began programs of support in a small group of countries to promote excellence in research. The initial projects and project components for this purpose (in Chile, República Bolivariana de Venezuela, Mexico, and Brazil) were grouped together under the Millennium Science Initiative (MSI). The motivation behind creating the MSI was to provide the framework for a highly selective process to make large grants available for grantees to perform scientific work of "international-level quality." The Bank's rationale for funding the MSI extended beyond improving research output alone, however. The MSI was also established as a means to catalyze efficiency gains and to demonstrate that improved funding processes can vastly improve the performance of S&T systems as a whole, including the quality of human capital training opportunities and the strength of links to the private sector. Countries from different regions are now participating in the MSI (Uganda) or considering participation (Bangladesh, Kazakhstan, Tanzania).

Results from the first MSI loan, a Learning and Innovation Loan to Chile, are now available. They reveal that a small investment in quality—$15 million in total—has leveraged a doubling of the production of doctorates in Chile, increasing the figure from 40–50 doctorates per year in science and engineering to an expected rate of 90–100 when the first MSI doctoral candidates graduate. In addition, quality across the Chilean science system is up sharply and outreach activities to the private sector and the education community have strengthened, surpassing expectations. Six patent applications have been filed in two years, some of which have high potential economic impact. Finally, international links have been fortified and the profile of research in Chile has been raised as the entire Chilean S&T system has benefited from the changes wrought by the MSI.

There are several ways in which the success realized in the MSI pilot group generalized across the entire Chilean S&T system. First, Chile's main funding agency has adopted the more transparent allocation processes used by the MSI. Second, researchers use the MSI as a positive example in dialogue about further improvements to Chile's system. Third, Chile has hosted regional S&T policy meetings under the auspices of the MSI. And fourth, the government has embarked on a follow-on project that would seek to generalize the reforms demonstrated under the MSI Learning and Innovation Loan (LIL).

Factors for success have been identified from the experience of Latin American and Caribbean (LAC) countries' MSI: (1) subsidiarity in government vision and policies; (2) congruence in government priorities and sector practices; (3) ownership of the program by the main government stakeholders and beneficiaries; (4) resistance to the risk of neglecting basic science and social sciences; and (5) existence of emerging, cohesive, and committed research teams of critical size.

It has been learned that beneficiaries and stakeholders respond positively to being judged on transparent and objective selection procedures, even when they do not win. This, in turn, is supported by transparency in communication, which can be facilitated by international participation (peer reviews, program committees, external program reviews, and supervision). In addition, grants need to be large enough to allow research groups to compete at or near the levels of the best researchers in the world. There should be a horizon of relative stability, with continuity in funding and coherence of science policy. A final lesson learned is to recognize that autonomy in the spending of resources by researchers and diminished bureaucratic burdens on the program management side are crucial to making science effective.

Source: Adapted from Watson, Crawford, and Farley (2003) with additions contributed by Lauritz Holm-Nielsen

Other (Nonlending) World Bank S&T Initiatives

72. In addition to funding project-specific S&T strengthening efforts through its lending programs, the World Bank has undertaken support of science and technology for development

through a variety of ventures across geographic and sectoral areas. One such initiative, the SPAAR—established in 1985 by a group of donors under World Bank leadership—is an open coalition that aims to further the contribution of agricultural research to food security, environmental sustainability, and economic development in Africa. The program promotes reforms of agricultural research institutions aimed at enhancing their sustainability and effectiveness, with a particular focus on building local capacity. SPAAR has been instrumental in the development of sub regional agricultural research organizations throughout Africa. A recent evolution of the SPAAR is the Forum for Agricultural Research in Africa (FARA). FARA is an umbrella organization for agricultural research stakeholders in Africa, serving as a knowledge hub in which research centers, nongovernmental organizations (NGOs), farmers' organizations, and the private sector share and exchange experiences.

73. Also in support of agriculture and rural development, the Bank cosponsors and hosts the secretariat of the CGIAR, an informal association formed in 1971 that supports 16 IARCs. These centers conduct research aimed at increasing productivity, protecting the environment, saving biodiversity, improving policies, and strengthening national research. The accomplishments of the CGIAR range from agricultural productivity enhancement of staple crops to improved water management, making the group universally recognized as an integral and irreplaceable part of the long-term development agenda.

Box 3: Knowledge for Development, World Bank Institute

The World Bank Institute's **Knowledge for Development Program (K4D)** builds the capacity of client countries to access and use knowledge to strengthen their competitiveness and increase their economic and social well-being. The program works with clients to design and develop realistic and achievable knowledge strategies. It helps countries assess how they compare with others in their ability to compete in the knowledge economy and to identify appropriate policies to help them achieve their goals.

The K4D program offers four main product lines to clients:

1. **Policy services**, including policy reports and policy consulting advice on various aspects of the knowledge economy (KE). K4D undertakes KE assessments, and provides recommendations in varying levels of detail as required by the client country. In FY04, K4D prepared KE assessments for India, Serbia and Montenegro, Bosnia and Herzegovina, Tanzania, Morocco, and others.
2. **KE studies** that are designed to bring together global learning and experience on the knowledge economy. Current studies include work on how developing countries can effectively strengthen their National Innovation Systems for the creation, use, adaptation, and dissemination of knowledge and technology, as well as KE country case studies on Finland, Korea, and Japan.
3. **Learning events**, including skill-building activities to build knowledge and skills for clients and Bank staff, as well as events (such as conferences) to facilitate the exchange of knowledge, experiences, and good or best practice on the KE. In FY04, K4D hosted a series of Global Innovation workshops using GDLN.
4. **The Knowledge Assessment Methodology (KAM)** is an Internet-based benchmarking tool for undertaking country knowledge assessments. It shows how an economy compares with other countries and helps to identify the problems and opportunities that a country faces in making the transition to the knowledge economy. The KAM is constantly being updated and currently contains data for 121 countries and for 76 KE indicators.

Source: Contributed by Carl Dahlman, former program manager, Knowledge for Development, World Bank Institute.

74. The Special Program for Research and Training in Tropical Diseases (TDR) is an international technical cooperation program, established in 1975 under the cosponsorship of the United Nations Development Programme, the World Bank, and the World Health Organization. Through partnerships with research institutions, ministries of health, disease control programs, industry, academia, and other organizations; TDR pursues its goals of (1) developing new methods of prevention, diagnosis, treatment, and control of the major tropical diseases; and (2) strengthening the capability of developing endemic countries to undertake tropical health research on their own. These research and training objectives are essential components of the Bank's S&T-related efforts.

75. The Bank's S&T portfolio contains several other initiatives in diverse fields and with many partners, also including the InfoDev Program—designed to assist the developing world in reaping the benefits of information and communications technologies—and the Global Environmental Facility—charged with facilitating international cooperation and financing efforts to deal with threats to the environment. Finally, the World Bank Institute's Knowledge for Development Program (see box 3) has produced major reports on Korea, China, Mexico, Chile, the Russian Federation, and India, all of which include chapters on science and technology and innovation.

CONCLUSIONS

76. Maybe with the exception of long-term support to agricultural research, the analysis of S&T projects over the last 25 years reveals no consistent approach or strategy on the part of the Bank toward developing S&T capacity in its client countries. In agriculture, sustained effort has been put into supporting NARS, much of which has been in the form of minor support undertaken in connection with other rural development activities. Ten to 15 clients, by contrast, hold loans that focus principally on improving agricultural research capacity. Similarly, for nonagricultural S&T projects, efforts have been concentrated on a dozen larger, more scientifically advanced countries. A few countries in two regions, East Asia (Korea, China, India, Indonesia) and Latin America (Brazil, Mexico, Chile), have maintained science and technology as a constant national priority. With the exceptions of Korea and Chile, these have tended to be large countries with low to middle incomes. Smaller countries have been more likely to ask for assistance in tertiary technical studies or with technical standards related to trade liberalization.

77. Regarding agricultural projects, there is ongoing work (Janssen, Pehu, Rajalahti, and Woelcke 2005) to define a new operational concept: the National Agricultural Innovation System (NAIS), as an expansion of the NARS concept. An NAIS methodology would be developed to guide the Bank's activities in agricultural science and technology. An upcoming review (Rygnestad, Rajalahti, and Pehu 2004) would allow for a better understanding of project design and implementation, presenting findings for 22 projects approved in FY04 on the following topics: (1) targeting of disadvantaged groups and producer organizations; (2) inclusion of different stakeholders and of different sectors other than agriculture; (3) level of institutional reform, including decentralization; (4) focus on topics related to integrated pest management, livestock production, cash and food crops, and agricultural biotechnology; and (5) use of

different implementation vehicles, including competitive grants, cost-sharing, and information technology.

78. Regarding nonagricultural projects in general, the Bank's approach has been ad hoc, experimenting with different mechanisms for different circumstances as they occurred. In this context, the MSI constitutes an attempt to move beyond the ad hoc approach. Human resource development and technology development appear to have been persistent priorities in general and account for the most resources. The rationale for interventions in this area has often been based on a desire to improve the efficiency and effectiveness of science funding systems, as well as the accompanying allocation mechanisms. In more recent projects, concern has been stressed to improve transparency and to develop better indicators, probably in reaction to several ICRs that faulted projects for not having the correct indicators of impact. Many projects are input focused and cite as a principle achievement the provision of infrastructure to scientists and researchers. Larger projects have also helped countries minimize the damage to their S&T systems during periods of fiscal and financial crises. Tracer studies of employment of graduates have been rare, as have serious attempts to devise monitoring indicators that respect the time lag inherent in research.

79. There is clearly room for the Bank's S&T projects to sponsor greater cooperation among client countries, and a first step toward this should be more interaction among the Bank staff who works on S&T issues. Clearly, opportunities are arising around recent projects and projects in preparation. These are more comprehensive S&T projects, ranging from basic education to promoting innovation systems, to supporting venture capital funds, to using Knowledge Economy/Information Society/Knowledge Society frameworks. Finally, there are already several solid systematizations of policy and design elements that should help new projects maximize their development impact. In addition to the agricultural reviews by Byerlee and Alex (1998, 2003)—with clear lessons to nonagricultural projects on *demand-driven and participatory research*—annexes D, E, and F include policy options according to country development stages, potential project interventions organized following the "Four Pillars of the Knowledge Economy," and S&T inputs necessary for the attainment of the Millennium Development Goals, respectively.

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REFERENCES

Byerlee and Alex. 1998. "Strengthening National Agricultural Research Systems: Policy Issues and Good Practice." World Bank Environmentally and Socially Sustainable Development, Rural Development Paper, Washington, DC.

Byerlee and Alex. 2003. "Designing Investments in Agricultural Research for Enhanced Poverty Impacts." World Bank Agriculture and Rural Development Working Paper, no. 6, Washington, DC.

Goel, Koryukin, Bhatia, and Agarwal. 2004. "Innovation Systems: World Bank Support of Science and Technology Development." World Bank Working Paper, no. 32, Washington, DC.

Janssen, Pehu, Rajalahti, and Woelcke. 2005. "Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Systems?" Proposed World Bank Economic and Sector Work, Washington, DC.

Lele. 2004a. "The CGIAR at 31: An Independent Meta-Evaluation of the Consultative Group on International Agricultural Research." World Bank Operations Evaluation Department, Washington, DC.

Lele. 2004b. "Global Health Programs, Millennium Development Goals, and the World Bank's Role." Global Public Policies and Programs Study Background Paper, World Bank Operations Evaluation Department, Washington, DC.

Patrinos. 2001. "Major Knowledge Initiatives of the World Bank Group: Relevance for World Bank Education Sector Lending and Research." World Bank, Washington, DC.

Rygnestad, Rajalahti, and Pehu. 2004. "Sustainable Agricultural Systems, Knowledge and Institutions (SASKI) FY 04 Portfolio Review." Draft World Bank document, Washington, DC.

Ware, el Hage, Rinaldi, and Thulstrup. 2002. "World Bank Lending for Secondary School Science: A General Operational Review." World Bank PHREE Background Paper Series, Washington, DC.

Watson, Crawford, and Farley. 2003. "Strategic Approaches to Science and Technology in Development." World Bank Policy Research Working Paper, no. 3026, Washington, DC.

Weiss and Jequier. 1984. *Technology, Finance and Development: An Analysis of the World Bank as a Technological Institution.* Lexington Books.

World Bank. 1999. *World Development Report: Knowledge for Development; 1998-1999.* Washington, DC.

World Bank. 1996. "Reforming Agriculture: the World Bank Goes to Market." OED Report, Washington, DC.

World Bank. 1980–2004. Annual Reports. Washington, DC.

World Bank. 1980–2004. Projects' Staff Appraisal Reports (SARs), Project Appraisal Documents (PADs), Project Status Reports (PSRs), Status of Projects in Execution (SOPEs), and Implementation Completion Reports (ICRs). Washington, DC.

ANNEX A: METHODOLOGY FOR IDENTIFYING SCIENTIFIC AND TECHNOLOGICAL PROJECTS, 1980–2004 REVIEW

An initial broad list of nonagricultural projects was generated by reviewing the brief descriptions for all such projects published in the World Bank Annual Reports for 1980–2004. Information on agricultural projects was compiled for the years 1981–96 in the 1998 publication by Byerlee and Alex, "The World Bank's Role in Strengthening National Research Systems," chapter 4 of "Strengthening National Agricultural Research Systems: Policy Issues and Good Practice" (agricultural projects approved in 1980 and 1997–2004 were examined separately to supplement the review). Any project that might possibly have an S&T component was included in this initial list. Next, a number of projects were eliminated after reviewing their development objectives and main project activities as listed in the Project Status Reports (PSRs), Staff Appraisal Reports (SARs), or Project Appraisal Documents (PADs). Projects were considered major S&T projects if at least 50 percent of total project costs went toward activities defined herein as S&T components. Implementation Completion Reports (ICRs)—which, like PSRs, evaluate project performance—were sometimes used for projects that have already been completed.

Projects were selected or rejected based on the best available information. Still, it is possible that, because of any discrepancies between the project summaries and the actual project details, some projects with significant S&T components may have been inadvertently omitted.

Frequently throughout the paper, two groups of projects are referenced—agricultural and nonagricultural projects. This is due to the incorporation of agricultural research data for the years 1981–96, published in previous World Bank studies, combined with data (for the entire review period) from World Bank agricultural sector databases. The only original research on agricultural science and technology conducted for this review pertains to projects approved in fiscal years 1980 and 1997–2004. Because of the differences between the previous and current reviews, the information does not always dovetail perfectly. For this reason, sometimes these two groups will be treated together—as "all" S&T lending—and sometimes they will be treated separately.

Finally, because of the broad scope of this review, which covered all sectors throughout 25 years of lending by the Bank—which approves, on average, 240 projects per year—we did not examine the details of all projects, but only those that generally appeared to meet our criteria in the initial phase of review. The agricultural reviews from which we have drawn seem to have considered all the projects undertaken within that individual sector more closely from the outset; thus, many agricultural projects with even small components are included. This will account for some of the apparent differences in treatment of agricultural and nonagricultural lending in this review.

Table A1: Total World Bank Lending and S&T Costs, 1980–2004 (US$ millions)

FY	All WB Lending	All S&T Costs	S&T/All Lending (%)
80	11,514	865	7.5
81	12,291	733	6.0
82	13,016	288	2.2
83	14,477	611	4.2
84	15,522	1,110	7.2
85	14,384	1,427	9.9
86	16,399	341	2.1
87	17,674	310	1.8
88	19,221	546	2.8
89	21,367	333	1.6
90	20,702	1,258	6.1
91	22,686	1,855	8.2
92	21,706	1,656	7.6
93	23,696	630	2.7
94	20,836	845	4.1
95	22,522	859	3.8
96	21,352	564	2.6
97	19,147	446	2.3
98	28,667	1,242	5.1
99	29,148	1,190	4.1
00	15,276	123	0.8
01	17,251	294	1.7
02	19,519	208	1.1
03	18,513	549	3.0
04	20,080	199	1.0
Total	**476,966**	**18,481**	**3.9**

Table A2: Major Support Projects and Minor Support Projects, 1980–2004 (US$ millions)								
	Major S&T Projects				Minor S&T Projects			
FY	**Number**	**S&T Cost**	**Project Costs**	**Loan Amounts**	**Number**	**S&T Cost**	**Project Costs**	**Component as % of Project**
80	4	839.3	931.1	243.0	10	25.3	824.1	3.1
81	4	466.8	576.7	314.0	33	265.2	4,030.5	6.6
82	3	157.5	209.5	75.5	28	130.0	3,436.6	3.8
83	4	536.7	608.5	263.5	37	73.9	3,243.2	2.3
84	3	777.8	789.4	160.5	35	331.7	3,493.8	9.5
85	6	501.9	562.1	204.3	40	925.3	5,744.2	16.1
86	3	246.8	302.6	187.1	29	94.5	6,390.7	1.5
87	4	173.1	203.8	93.4	33	136.4	2,800.0	4.9
88	4	417.7	417.7	119.5	19	127.9	2,208.1	5.8
89	6	148.2	211.2	102.9	23	184.4	2,630.7	7.0
90	9	940.2	1,166.8	691.9	30	317.8	3,339.2	9.5
91	9	1,635.6	1,726.7	1,006.3	21	219.7	2,417.1	9.1
92	7	1,453.2	1,663.2	659.0	26	212.6	2,463.3	8.6
93	5	434.6	484.5	302.0	24	195.0	2,247.1	8.7
94	5	632.9	648.7	393.6	30	212.1	4,896.4	4.3
95	5	583.3	629.9	343.0	25	276.0	2,994.5	9.2
96	5	406.9	534.3	333.9	26	157.0	2,827.8	5.6
97	5	406.1	672.4	314.1	11	39.9	847.6	4.7
98	5	1,202.2	1,316.1	633.6	3	40.0	128.1	31.2
99	6	988.2	1,019.8	501.5	5	201.6	890.7	22.6
00	5	77.56	97.33	56.83	4	45.25	197.13	23.0
01	5	183.65	248.13	159.4	9	110.5	1267.94	8.7
02	3	111.03	218.4	130.8	9	96.74	692.7	14.0
03	3	422.4	437.16	329.26	7	126.1	769.1	16.4
04	1	53.7	70.4	27.0	11	145.4	905.09	16.1
Total	**119**	**13,797**	**15,746**	**7,646**	**528**	**4,690**	**61,686**	**7.6**

Note: As already mentioned, the agricultural data capture many more projects with small S&T contributions than does the review of projects in the other sectors. Because of the apparent differences in method of review between the agricultural and current studies, the figures for 1980 and 1997–99 are significantly lower in two categories. The S&T costs for those years do not necessarily vary by a clear margin (as many agricultural project components are small), but the number of projects listed, and especially the overall project costs, differ dramatically for those years. Still, these costs help to complete the S&T lending picture and have value as notional figures. Even correcting for those four years, the average number of minor projects goes from 24.4 projects up to only 28.7 projects per year, and the overall percentage of total project cost represented by S&T components changes very little, from 7.2 percent to 7.6 percent.

ANNEX B: DESCRIPTION OF SELECTED MAJOR NONAGRICULTURAL PROJECTS IN CHILE, CHINA, INDIA, KOREA, MEXICO, AND TURKEY

(Reproduced with permission from Goel, Koryukin, Bhatia, and Agarwal, 2004.
"Innovation Systems: World Bank Support of Science and Technology Development."
World Bank Working Paper, no. 32.)

Box B1: Republic of Korea

Electronics Technology Project
Project approved: 1979. Project completed: 1986. Total amount: $29 million
The project supported setting up and development of Korean Institute of Electronics Technology (KIET). The project was to support KIET as a central facility in semiconductor industry, including exploring and developing export opportunities for the Korean electronics sector overseas. The project played a catalytic role in building the electronics sector in Korea. However, the project did not meet some of its objectives, including profitability targets and industry-related research and development (R&D) programs because of the situation in the country when the industry started to invest heavily into semiconductors research, leaving less room for KIET, and other economic and business conditions in Korea.

Technology Development Projects (First, Second, and Third)
Projects approved: 1982, 1984, 1988. Projects completed: 1986, 1989, 1992. Total loan amount: $129 million
The Technology Development Projects were a series of projects designed to foster the technological development of industry in the Republic of Korea through the financing of the Korea Technology Development Corporation (KTDC) and the strengthening of three key institutions: KIST, one of Korea's leading multidisciplinary research institutes; KSBC, the Korea Basic Science Center; and NITI. Support for KIST was intended to cover a broad spectrum of applied research activities and to recruit high-quality researchers; KBSC was established to provide more opportunities for joint basic science research, the foundation of technological innovation; and the role of NITI was to support small and medium enterprises (SMEs) by raising product quality. KTDC helped create links between the R&D institutes and industry, supported SMEs through the financing of technology start-ups and technological support, and formulated technology policy and appraised national joint R&D projects between SMEs and industry.

Technology Advancement Projects (First, Second, and Third)
Projects approved: 1989, 1990, 1991. Projects completed: 1993, 1994, 1994. Total loan amount: $108 million
The Technology Advancement projects were a series of projects aimed at providing funds for the purchase of modern equipment for the five main national Research and Development Institutions (RDIs). The broad objective of this initiative was to strengthen industrial R&D and basic research capacity and to increase the use of industrial standards to raise product quality. These objectives were in conformity with government policy, which sought to expand and strengthen vocational, technical, and tertiary education in science and engineering and to support public and private R&D activities as Korea sought to join the ranks of the industrial countries. The availability of the new equipment and facilities made it possible for the RDIs to increase their R&D activities and joint projects, expand their testing for quality improvements, and increase their output of technical and scientific publications.

Program for Science and Technical Education Project, Universities Science and Technology Research Project, Science Education and Libraries Computerization Project
Projects approved: 1984, 1990, 1992. Projects completed: 1989, 1995, 1997. Total loan amount: $195

million
The Program for Science and Technical Education aimed to raise the quality of S&T education to the level required by an industrial system that sought to be more skill- and knowledge-intensive and that was moving toward the use of more advanced technologies. The Universities Science and Technology Research Project aimed to help selected universities strengthen their ability to undertake research in science and technology and strengthen their science teacher education, with the goal of raising the quality of science education in secondary schools. The Science Education and Libraries Computerization Project aimed to help improve the quality of basic science education and to provide a more effective flow of information among those university libraries that service teaching and research.

Box B2: China

Rural Industrial Technology (Spark) Project
Project completed: December 1997. Loan amount: $114 million
The Ministry of Science and Technology's pilot Spark program became nationwide in 1986. The overall objective of the program was to help transfer technological and managerial knowledge from the more advanced sectors of the economy to rural enterprises to support growth and development in the nonstate rural enterprise sector, mostly town and village enterprises, and to help increase output and employment. This project was the first Bank Group–supported operation in China specifically oriented to the rural nonstate industry. The term "Spark" referenced the phrase "one small spark can start a prairie fire," reflecting the anticipated catalytic effect of the program on rural enterprise development.

Technology Development Project
Project approved: 1995. Loan amount: $200 million
The objective of this project is to support government reforms in technology policy and institutions, with the aim of promoting the development of clean, productivity-enhancing technologies in China's industries. The project is designed to accelerate the diffusion and adaptation of technologies in China and abroad through the deepening of technology markets and through institutional initiatives. The project consists of two components. The first component is designed to assist in transforming part of the R&D establishment into market-responsive technology development corporations. This component will hive off the most dynamic technology development and service-oriented elements of existing research institutions to create, through a competitive selection process, market-oriented Engineering Research Centers. The second component includes complementary investments aimed at improving public technology services, including the modernization of the National Institute of Metrology and a technical assistance program for a productivity center.

"China and the Knowledge Economy" Report—year 2000
At the request of the Chinese Government, the World Bank Institute conducted a Knowledge Economy Assessment in China in 2000 and published "China's Development Strategy: the Knowledge and Innovation Perspective, the World Bank, Washington D.C., 2000. (This report was used by the government as an input into the development of China's 10th Five-Year Plan.) This assessment concluded that China's strategy should be to build a foundation for a knowledge-based economy by (1) updating the economic and institutional regime; (2) upgrading education and learning; (3) building the information infrastructure and raising the technological level of the economy through the active diffusion of new technologies; (4) improving the R&D system; and (5) exploiting global knowledge.

Box B3: Mexico

Industrial Technology Development Project
Project approved: July 1986. Project completed: June 1993. Loan amount: $48 million
The project was designed to improve the capability of industry (especially private firms) to undertake the technological innovation needed to contend with the increasing competition that was expected because of the government's economic liberalization program. This project may have been premature, coming as it did in the early stages of what has been a profound transformation of Mexico's economy: conditions were not yet suited for private sector R&D and Mexico was going through one of its worst economic crises. The project nonetheless can be credited for having been a catalyst in the policy dialogue on science and technology and a factor in the ensuing changes in institutions and operational environment that are now providing a much more fertile ground for technological innovation. Studies financed under the project enabled the government to improve its project policy and infrastructure; the metrology studies additionally produced a number of significant findings on which the follow-up project was able to build.

Science and Technology Infrastructure Project
Project approved: May 1992. Project completed: June 1998. Loan amount: $189 million
The main objectives of this project were to rationalize public sector funding for science and technology and to develop technology institutions by supporting the restructuring of a science research program and improving the efficiency of public support. The project was successful in increasing the number of Mexican scientific research publications and their impact, significantly increasing the production of research-trained personnel, renewing the Mexican research instrumentation infrastructure, institutionalizing a merit-based peer review, and improving the efficiency of the National Science and Technology Council. The project supported the creation of the Mexican National Center for Metrology (CENAM), which now has 104 laboratories operational and which has helped to attract foreign investment and promote competitiveness in Mexican industry, and supported the creation of the Mexican Institute of Industrial Property, significantly reducing delays in the award of patents, increasing enforcement activities, and increasing inspections relating to Intellectual Property Rights (IPR) violations. The project was also successful in creating a supply of basic S&T infrastructure and in helping to sustain development of an R&D capacity.

Knowledge Innovation Project
Project approved: June 1998. Planned completion: June 2003. Loan amount: $300 million
The Knowledge and Innovation Project, approved in 1998 to support a third generation of reforms and to address some of the gaps remaining on completion of the S&T Infrastructure Project. Specifically, it was designed to enhance the effectiveness of research support programs while increasing links to user groups in society and industry. The project's development objectives were (1) to support S&T research by stimulating work in new and lagging fields, specifically by promoting quality in research, by consolidating and improving peer review, and by prioritizing the integration of young researchers into the system; and by overseeing the institutional strengthening of the scientific management research conducted by National Council of Science and Technology (CONACYT); (2) to support joint action between universities/public research institutes and the private sector, by restructuring public S&T institutes to increase cost recovery and reorientation to industry and by matching grants for joint industry-academia projects; and (3) to support the productivity and competitiveness of firms, particularly SMEs, through a technology modernization program to support upgrading with matching grants and through the development of private regional and sectoral institutional technology support centers.

Box B4: India

Industrial Technology Development Project

Project approved: December 1989. Project completed: June 1998. Loan: $200 million

The objective of this project was to facilitate the acquisition and development of technology by industrial firms in India. It aimed to balance existing domestic technological capability with the import of foreign technology and to reduce the financial constraints on new technology ventures and the foreign exchange constraint on technology imports. The project helped small, innovative firms obtain financing by supporting the development of venture capital (VC) in India, in the form of six VC companies managing nine VC funds. These VC companies invested in more than 300 firms, producing returns that have averaged 18–20 percent. The project, in essence, launched the VC industry in India, but its indirect contribution—introducing a culture of risk finance and thus attracting foreign venture capitalists to India—may have been equally important. The project additionally supported the upgrading of RDIs, providing technology services to industry and promoting collaboration between industry and research institutions. The project provided loans rather than grants, forcing the borrower institutions to focus on their financial management and rates of return. A number of research institutes were able to modernize and upgrade their physical facilities, enabling them to enter new areas of research and to reorient themselves to serve industry. Finally, the project also financed the importation of technology and technical know-how by supporting the fast-track Technology Development Fund, which put forward $100 million to benefit between 600 and 800 firms.

Technical Education Engineering Quality Improvement Project

Project approved: 2003. Loan: $250 million

This project aims to improve the quality of engineering institutions throughout India. The country has six Indian Institutes of Technology (IITs) that every year send a large percent of their graduates to work for foreign multinationals, both in India or abroad. Initially the project proposed increasing the number of IITs in India, but based on a Mashelkar Committee report, it was determined that upgrading existing regional engineering and technical institutions would be more resource-efficient and would produce a wider supply of qualified specialists to better meet the needs of industry. The institutions are being selected based on their willingness to accept academic, financial, managerial, and administrative autonomy, increase cost-recovery ratios, and so on. The number of institutions to be selected is expected to be between 20 and 25.

Box B5: Turkey

Technology Development Project

Project approved: May 1992. Project completed: June 1998. Loan amount: $100 million

This project had three broad objectives: (1) to develop the Metrology, Standards, Testing, and Quality (MSTQ) system; (2) to encourage market-oriented R&D in the private sector; and (3) to foster the growth of a VC industry. The project supported the establishment of an independent National Metrology Institute (UME), separating it from the Marmara Research Center. By the end of the project, UME was able to meet 30–40 percent of the needs of Turkish industry. The project supported modernization of the Turkish Standards Institute and improvement of the standardization processes; it also initiated an R&D financing culture in Turkey by setting up the Technology Development Foundation of Turkey (TTGV) a private sector-managed nongovernmental organization (NGO), and by funding the country's first technology financing program (103 R&D projects financed). However, a VC industry did not materialize because of a range of reasons, including the absence of necessary incentives for the private sector and a lack of support from the International Finance Corporation (IFC), which initially had been nominated as the main catalyst for this effort. The VC component was picked up by the follow-up project.

Industrial Technology Project

Project approved: June 1999. Planned completion: December 2004. Loan amount: $155 million

The main project objectives are to (1) assist in the harmonization of Turkish technology infrastructure with ECU standards, and (2) assist firms in upgrading their technological capabilities to improve the competitiveness of Turkish industry. To achieve these objectives, the project concentrated on four main areas: (1) strengthening of IPR services; (2) strengthening of metrology services to serve a larger section of Turkish industry; (3) restructuring of RDIs to make them more industry-oriented; and (4) supporting technology upgrades by firms (including the formation of a VC industry and the establishment of technology). The project follows up on the First Technology Development Project by continuing support to (1) UME, which is developing into a world-class metrology institution capable of meeting 95 percent of Turkish industry's metrology needs, and (2) the Technology Development Foundation of Turkey that is developing into a diverse technology financing institution that has changed the entire technology financing culture in Turkey. In addition, the Project supports (1) restructuring the public R&D system in Turkey through reconfiguration of Marmara Research Center (MAM, a group of eight leading RDIs), and (2) upgrading the Turkish IPR regime by strengthening Turkish Patent Institute (TPE). As a result of the project investments, by end-2003 (1) UME is capable of meeting 80 percent of the industry's metrology needs and provides about 500 services to the industry; (2) TTGV, in addition to its original technology financing mandate (it has financed some 200 projects to date), has become a catalyst in supporting VC funds (two VCCs were set up with TTGV's equity participation) and also supports two techno parks—in addition, its competitive Technology Support Services (TSS) grant scheme for advisory services has benefited about 600 SMEs; most of TTGV's projects have resulted in the commercialization of R&D outputs; (3) MAM has increased its contractual research base and industry outreach, and was about 49 percent self-sufficient in 2003, targeting 65–70 percent self-sufficiency by 2006; and (4) the IPR regime is improving its alignment with ECU and World Trade Organization requirements, and TPE is developing into an international-level institution.

Box B6: Chile

Millennium Science Initiative
Project dates: 1999–2002. Loan amount: $5 million
This project consisted of three components and aimed at creating (1) a management structure for the Millennium Science Initiative; (2) a competitive fund for scientific excellence; and (3) a network for the promotion of scientific excellence.

Science for the Knowledge Economy (Phase I)
Project planned: 2003–2007. Loan amount: $25 million
Given the long-term commitment that is necessary to consolidate institutional and behavioral changes in the S&T sector, a program approach is proposed for Chile that would use the Adaptable Program Lending (APL) instrument. The program comprises two phases. The first phase, Science for the Knowledge Economy, extends until 2007 and supports the establishment of a strong policy framework. It also will provide for the continuation of the Millennium Science Initiative and a further strengthening of the science base. The second phase (2007–10) will continue the activities to strengthen Chile's science base, with a view particularly to enhancing private sector R&D. A further phase aimed at improving the innovation system is planned for fiscal 2006.

ANNEX C: TABLES AND BOXES EXEMPLIFYING IMPACT OF AGRICULTURAL RESEARCH ON POVERTY REDUCTION

(Reproduced with permission from Byerlee and Alex, 2003.
"Designing investments in Agricultural Research for Enhanced Poverty Impacts."
World Bank Agriculture and Rural Development Working Paper, no. 6.)

Box C1: Impact of Past Agricultural Research on Poverty Reduction

Substantial evidence indicates that the poverty reduction impact of agricultural research investment is high compared with other public investments. In India, agricultural research had the highest productivity impact and the second highest poverty reduction effect after rural roads. One million Rupees spent on agricultural research reduces the number of poor by 90 persons. Likewise, in China, the impact of Yuan 100,000 on poverty reduction is higher than for all other investment except education (Fan, Zhang, and Zhang 2000; Fan, Hazell, and Thorat 1999).

Number of persons removed from poverty for a given public investment

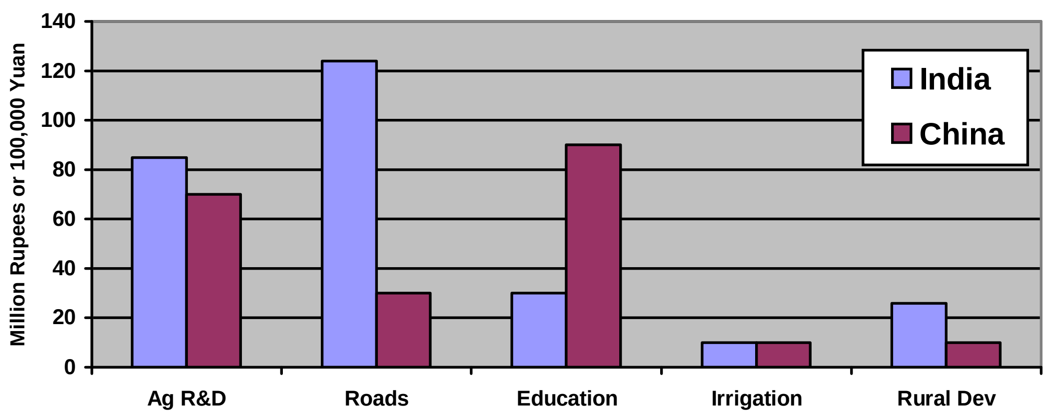


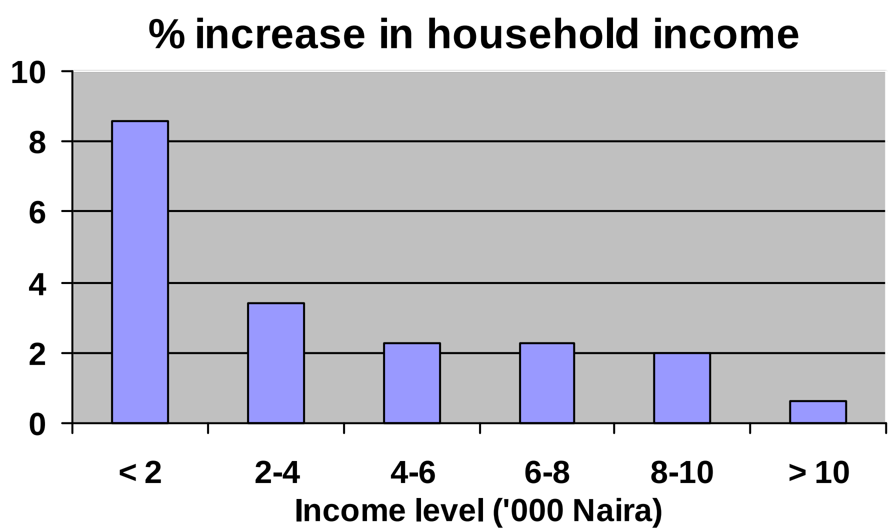
Table C1: Estimated Rates of Return to Investment in Agricultural Research

Region	Number of estimates	Median rate of return
Africa	188	34
Asia	222	50
Latin America	262	43
Middle East/North Africa	11	36
All developing countries	683	43
All developed countries	990	46
All	**1,772**	**44**

Source: Alston and others (2000), as appears in Byerlee and Alex (2003).

Box C2: Distribution of Benefits of Cassava Research in Nigeria

Cassava is the most important food staple in Nigeria. The Nigerian Roots and Tubers Research Institute, in collaboration with IITA introduced improved cassava varieties in the 1980s that resulted in yield increases of about 30 percent on 50 percent of the cassava area. Afolami and Falusi (1999) estimated that consumers captured 72 percent of the benefits of this research through lower prices and that poorer consumers captured a disproportion share of these benefits. And because poor farmers consume most of their produce, they gained relative to larger farmers.



Box C3: Eradicating Childhood Blindness in Africa

Agricultural research is helping address the problem of vitamin A deficiency that threatens hundreds of thousands of African children with childhood blindness and contributes to infant mortality. Researchers have identified orange-fleshed sweet potato varieties that provide a year-round source of vitamin A, produce excellent harvests with little inputs, and are acceptable to consumers. This is particularly important in southern and eastern Africa where vitamin A–related diseases are widespread, and the traditionally grown sweet potatoes are white-fleshed varieties with little or no beta-carotene (a precursor of vitamin A). Participatory methods with largely female and poor farmers, who are the main producers and consumers of sweet potatoes, have shown that the orange-fleshed varieties are also acceptable to consumers. The new varieties have now been extensively adopted. Research has shown that even small amounts of the new sweet potato varieties in the diet can eliminate vitamin A deficiencies.

Source: CIP (2002).

Table C2: Crop Biotechnologies to Meet Needs of Poor Farmers and Consumers

Technique	*Biotechnological Solution*
Tissue culture—plant micro-propagation to produce healthy plants	This relatively low-cost technology has been adopted by poor farmers for bananas in China, taro in Samoa, multipurpose trees in Kenya, potato in Vietnam, and cassava in Colombia.
Anther culture (a subcategory of tissue culture) to reduce time needed for interspecific crosses	Crosses between Asian and African rice varieties resulted in new African rice varieties with higher yields and pest, weed, disease, and climatic tolerance relative to traditional varieties. Poor farmers in upland rice areas of West Africa are now rapidly adopting these varieties.
Molecular markers to identify, more precisely, genes for specific characteristics and thus speed conventional breeding	Molecular markers are being employed in many breeding programs, including breeding for sweet potato viruses (important to poor producers) and for quality protein maize (important to poor consumers).
Genetic engineering to insert genetic material into crop and livestock species	Some genetically modified products are being commercialized and widely adopted (Bt cotton for insect resistance in South Africa, Mexico, and China); others are under field testing (that is, virus-resistant sweet potatoes and potatoes, Bt maize for insect resistance, and rice with late blight resistance). Many others under development offer traits of special significance to the poor (potatoes with higher protein, enhanced vitamin A rice, and rice with salinity tolerance).

Table C3: Summary of Pro-Poor Institutional Approaches

Investment Principle	*Objective*	*Pro-Poor Implementation*	*Examples*
Focus public programs on public goods	To ensure that government programs benefit the general public and do not crowd out private funding of research.	Give priority to poverty reduction and food security. Phase out public sector investment in private goods.	Privatization of research on appropriable technologies (for example, hybrid maize) Farmer controlled levies on commercial crops and reduced public funding
Institutional pluralism	To encourage development of a range of public and private institutions with unique comparative advantages in the provision of research.	Involve nongovernmental organizations (NGOs) and producer organizations that tend to have a pro-poor orientation.	Competitive funding through producer associations (Colombia, Guinea)
Use of participatory approaches	To empower local communities, tap local knowledge and resources, and provide services that suit local conditions.	Mobilize the poor and develop their initiative and problem-solving ability. Work through, and strengthen, producer organizations and NGOs.	Local Agricultural Research Committees (CIALs) (Latin America)
Build culture, incentives, and methodologies for pro-poor responsiveness and collaboration among agents	To enhance responsiveness and effectiveness in dealing with pro-poor programs under conditions of increasing livelihood vulnerability.	Improve institutional arrangements for collaboration among research and extension actors and their clients within pro-poor programs. Conduct socioeconomic studies of poor client needs and resources.	National and regional innovation councils and regional technology for a
Decentralization of operational authority and responsibilities	To increase user influence over programs by devolving responsibilities to the regional level.	Encourage regional governance mechanisms with stakeholder voice representing the poor.	Regional fora with strong participation of minority groups and women (Peru and Colombia)
Building human and social capital	To promote emergence of a new generation of institutions representing the rural poor.	Finance capacity development of producer organizations. Strengthen agricultural education and training programs.	Investment in capacity building of producer organizations and private service providers
Cost-sharing by major stakeholders	To enhance financial sustainability of research programs by sharing the burden of funding among central and local governments, the private commercial sector and farmers.	Recognize trade-offs between financial sustainability and participation of the poor. Use graduated payment schemes to require larger farmers to pay a greater percentage of program costs than poor farmers.	Decentralized research funds (Peru and Mexico)

Box C4: Farmer-run Research: Experience with the CIALs

Turning responsibility for on-farm testing over to farmers is an attractive alternative that has been extensively tested by Centro Internacional de Agricultural Tropical (CIAT) in several National Agricultural Research Systems (NARSs) of Latin America. Under the CIAL program (CIAL is the Spanish acronym for Local Committee for Adaptive Research), begun in 1990, an institution with interest in technology dissemination (usually a state agency, NGO, or cooperative) facilitates a meeting in which a community analyzes potential needs for local technology testing. If the community is interested in undertaking local research, it selects a four-member committee (the CIAL) from the community to coordinate the research work. Outside technical staff from the organizing institution assist in planning and analysis of research trials and a paraprofessional (a CIAL-experienced farmer) monitors and advises on the research. Technical staff visit two to three times per season after the first two to three seasons. CIALs operate with a small CIAL Fund ($500 per community) to cover the risks of crop failure or to subsidize the costs of trials. These CIAL funds have been consolidated into a corporation at the national level, but each CIAL manages its own fund. The funds, like the whole program, are "owned" by the community and managed by the committee.

Source: Ashby and others (2000).

Box C5: Beneficiary Assessment

Beneficiary assessment is used to gather information on users' views of programs and services. Beneficiary assessment is primarily a management tool to assist managers in improving quality and relevance of services. Conversational interviews and group discussions elicit information from services, users, providers, and stakeholders to identify program strengths and weaknesses. Beneficiary assessments have most commonly been used for extension programs, where they have been useful in understanding weaknesses and strengths of the programs and have led to important changes in policy for service delivery. EMBRAPA, the national research organization in Brazil, conducts an annual survey to provide feedback from users.

Source: Salmen (2000).

ANNEX D: SCIENTIFIC AND TECHNOLOGICAL POLICY OPTIONS BY COUNTRY GROUPING

(Reproduced with permission from Watson, Crawford, and Farley, 2003.
"Strategic Approaches to Science and Technology in Development."
World Bank Policy Research Working Paper, no. 3026.)

Policy Options by Country Grouping			
THE COUNTRY GROUPING HERE ARE THOSE PROPOSED BY THE RAND CORPORATION'S MATRIX ON S&T CAPACITY IN THE DEVELOPING WORLD. THE MATRIX IS ONE OF THE FIRST TO ATTEMPT SUCH A THOROUGH CLASSIFICATION. IT HAS MANY STRENGTHS AND WEAKNESSES, AND THE POSITION OF ANY SINGLE COUNTRY IN THIS MATRIX IS SUBJECT TO DEBATE AND FURTHER SCRUTINY. IT IS IMPORTANT TO READ THE EXPLANATORY FOOTNOTE TO FULLY UNDERSTAND WHAT THIS GROUP DOES AND DOES NOT PURPORT TO SHOW.[5]	24 Scientifically Proficient Countries: Belarus, Brazil, Bulgaria, China, Croatia, Cuba, the Czech Republic, Estonia, Greece, Hungary, India, Lithuania, Luxembourg, New Zealand, Poland, Portugal, Romania, Singapore, the Slovak Republic, Slovenia, South Africa, Spain, Ukraine	24 Scientifically Developing Countries: Argentina, Armenia, Benin, Bolivia, Chile, Colombia, Costa Rica, Arab Republic of Egypt, Hong Kong, Indonesia, Iran, Kuwait, Latvia, Macedonia FYR, Mauritius, Mexico, Moldova, Mongolia, Pakistan, Serbia and Montenegro, Turkey, Turkmenistan, Uzbekistan, Venezuela, R. B. de	80 Scientifically Lagging Countries: Burundi, Central African Republic, Congo, Dem. Rep. of, Ecuador, Gabon, Georgia, Guatemala, Iraq, Kazakhstan, Kyrgyz Republic, Nepal, Panama, Peru, Sri Lanka, Syrian Arab Rep., Tajikistan, Togo, Tunisia, Uganda, United Arab Emirates, Uruguay
Policies for Human Resources Development	Policies for Primary and Secondary Education • Further strengthen science curricula in the basic and secondary sciences, ensuring the use of hands-on approaches to teaching, student access to ICTs, etc. • Utilize the results of international student achievement assessments, such as the TIMSS and PISA in the reform and modernization of basic and secondary sciences curricula Policies for Technical, Scientific, and Engineering Education • Further promote diversification in knowledge	Policies for Primary and Secondary Education • Strengthen science curricula in the basic and secondary sciences, ensuring the use of hands-on approaches to teaching • Provide updated science teacher training • Utilize the results of international student achievement assessments, such as the TIMSS and PISA in the reform and modernization of basic and secondary sciences curricula Policies for Technical, Scientific, and Engineering Education • Promote diversification in knowledge delivery	Policies for Basic and Secondary Education • Incorporate basic science education into the primary- and secondary-level curricula • Provide sufficient training to primary- and secondary-level teachers so that they are prepared with the skills necessary to teach basic sciences • Benchmark effectiveness of student learning by participating in international assessments (e.g., TIMSS) Policies for Technical, Scientific, and Engineering Education

[5] The RAND country groupings resulted from a composite S&T capacity index of 150 countries created from available indicators of S&T investment, infrastructure, and output, including bibliometric literature patterns and interviews with U.S.-based scientists collaborating with scientists internationally. This was the first attempt to produce such a comprehensive classification, and it relied heavily on data that are proxies for more sophisticated measures of S&T capacity. Because of this, the groupings tend to reflect a country's potential to conduct S&T research, not the extent to which it has realized that potential. Therefore, some countries will appear in categories that do not correspond to perceptions of their actual performance, because they are exceeding or falling short of what the proxies indicate their capacity to be. It should be noted that since its publication in 2001, this matrix has garnered significant attention in the international S&T policy community, and three attempts have already been made or are under way to further refine the methodology and accuracy. As these become available, they will be reviewed and the country groupings may be revisited.

	delivery between institutes of different types from polytechnics to community colleges, distance education and adult learning centers and open universities • Foment relationships with the private sector to ensure market relevance of skills taught • Ensure equity in access to various types of postsecondary education Policies for Scientific Research and Graduate Study • Link the conduct of research and advanced training in the university setting to the productive sector through partnerships with national research laboratories publicly-funded incubators, etc. (See OED 1997) • Articulate a national research agenda to guide the funding, prioritization, and advancement of those specific fields of research with high importance to national development and international competitiveness • Expand grant programs for graduate study and research in disciplines of national interest (e.g., science and engineering) • Encourage conditions in the academic setting conducive to private sector investment in research	among institutes of different types from polytechnics to community colleges, distance education, and adult learning centers and open universities • Foment relationships with the private sector to ensure market relevance of skills taught Policies for Scientific Research and Graduate Study • Encourage the conduct of research and advanced training at home, to create the pool of highly trained specialists needed to access and use available knowledge and begin to advance the frontiers of new knowledge in certain areas of specialization most important for the country's development • Fund, manage, and develop regional centers of excellence in specific scientific and engineering disciplines • Link academia to the private sector for further relevancy of research and employability of researchers	• Foment relationships with the private sector to ensure relevance of skills taught to market needs • Allow for differentiation of foci among institutions (e.g., institute for specific vocations, automotive schools, etc.) • While ultimately housing high-quality universities with strong science and engineering departments is ideal, initially, regional centers of excellence with emphasis in specific disciplines may better satisfy the needs of the market given budget constraints Policies for Scientific Research and Graduate Study • Focus on creating a few centers of excellence in market-relevant areas of science and technology in which the country has a comparative advantage at the regional level • Provide grants for scientific research and training abroad coupled with incentive programs to return to minimize brain drain • Link national development priorities to areas of training and research and concentrate financing on building a few strong academic programs in the identified priority disciplines
Policies for Stimulating Demand for Knowledge in the Productive Sector	Implicit Policies • Open to trade and foreign direct investment to foster the inflow of knowledge • Allow for further deepening and diversification of credit markets as new types of firms emerge • Strengthen the IPR regime to provide incentives for innovation and R&D Explicit Policies • Increase information on the benefits of R&D through industry-academia links, initial subsidies for contract research with universities, student internships with firms, trade fairs, and other events to increase exposure to global buyers • Provide tax incentives to firms engaged in R&D and direct support to SMEs • Foster the creation of shared infrastructure and economies of scale for new firms via	Implicit Policies • Open to trade and foreign direct investment to foster the inflow of knowledge • Allow for the deepening and diversification of credit markets as new types of firms emerge • Establish the framework for an IPR regime to provide incentives for innovation and R&D Explicit Policies • Increase information on the benefits of R&D through industry-academia links, initial subsidies for contract research with universities, student internships with firms, trade fairs, and other events to increase exposure to global buyers • Provide tax incentives to firms engaged in R&D and direct support to SMEs • Foster the creation of shared infrastructure and economies of scale for new firms via technology parks and incubators, where appropriate • Establish a framework for the protection of	Implicit Policies • Establish basic macroeconomic stability, including curbed inflation, strong currency, and proper rates of savings and investment • Open to trade and foreign direct investment to foster the inflow of knowledge • Improve the credit environment for individuals and small businesses Explicit Policies • Establish a framework for the protection of indigenous knowledge • Subsidize firm-based training to encourage technology deepening

	technology parks and incubators	indigenous knowledge	
Policies for Public Support of S&T	Funding Science • Leverage benefits from privately performed research conducted through creative public-private partnerships • Provide public support for science and technology that is in the public interest and is unlikely to receive sufficient funding from the private sector Monitoring and Evaluating • Promote transparency, objectivity, and peer review and evaluation procedures in determining how to award discretionary research funding Governance and Regulation • Articulate a national science agenda balanced between various sectors and subsectoral S&T interests • Improve governmental regulatory capacity in areas concerning public health, public safety, and other areas relevant to science and technology • Ensure equal access to resources for training, funding, and performance across race, gender, etc. • Ensure policymakers' access to the necessary scientific expertise regarding areas for public debate and decision making	Funding Science • Leverage benefits from privately performed research conducted abroad and at home through creative public-private partnerships • Provide public support for science and technology that is in the public interest and is unlikely to receive sufficient funding from the private sector Monitoring and Evaluating • Promote transparency, objectivity, and peer review and evaluation procedures in determining how to award discretionary research funding Governance and Regulation • Promote a high level of openness and public scrutiny and understanding in the sciences • Articulate a national science agenda balanced between leveraging existing knowledge in the sciences and pursuing various areas of national interest and comparative advantage • Improve governmental regulatory capacity in areas concerning public health, public safety, and other areas relevant to science and technology • Improve metrology, standards, and testing to ensure adherence to international benchmarks for quality • Ensure equal access to resources for training, funding, and performance across race, gender, etc.	Funding Science • Leverage benefits from privately performed research conducted abroad through creative public-private partnerships • Let the magnitude and urgency of domestic challenges to development establish priorities for the national S&T agenda Monitoring and Evaluating • Promote transparency, objectivity, and peer review and evaluation procedures in determining how to award discretionary research funding Governance and Regulation • Articulate a national science agenda balanced between leveraging existing knowledge in the sciences and pursuing a few areas of national interest and comparative advantage • Prepare for improved governmental regulatory capacity in areas concerning public health, public safety, and other areas relevant to science and technology • Prioritize metrology, standards, and testing to meet international benchmarks for quality, measurements, etc. • Ensure equal access to resources for training, funding, and performance across race, gender, etc.
Policies for Increasing Access to ICTs	Policies for ICT Access • Extend access of available ICTs to a wider range of users Policies for ICT Use • Build out hard and soft infrastructures, including Internet and broadband networks • Provide support for the training and education of the human capital base with respect to ICT use, including technical education for the next generation of ICT workers, such as network technicians, computer programmers, Web developers, and database managers • Educate entrepreneurs and government officials as to how to exploit ICTs so that they may take the lead in developing knowledge economies	Policies for ICT Access • Extend access of available ICTs to a wider range of users Policies for ICT Use • Explore regional solutions to infrastructure creation (both hard and soft information infrastructures) • Provide support for the training and education of the human capital base with respect to ICT use, including technical education for the next generation of ICT workers, such as network technicians, computer programmers, Web developers, and database managers • Support the use of ICTs as pedagogic tools Policies for ICT Research • Pursue public-private partnerships in service delivery and research	Policies for ICT Access • Extend access of available ICTs to a wider range of users • Build out infrastructure to extend coverage Policies for ICT Use • Improve regulatory framework to facilitate conducive environment for ICT growth • Provide support for the training and education of the human capital base with respect to ICT use Policies for ICT Research • Scientifically lagging countries should generally concern themselves less with ICT-related knowledge creation and more with the challenges related to the expansion of overage, use, and access

	Policies for ICT Research • Support the use of ICTs as pedagogic and research-related tools • Provide incentives for ICT-related R&D • Pursue public-private partnerships in service delivery and research	• Promote research into the efficiency and quality gains potentially achievable in core industries with the additional application of ICT	

Note: ICT = information and communication technologies; IPR = intellectual property rights; PISA = Programme for International Student Assessment (of the OECD); OED = Operations Evaluation Department; R&D = research and development; S&T = scientific and technological; SME = small and medium enterprise; TIMSS = Trends in International Mathematics and Science Study.

ANNEX E: KNOWLEDGE ECONOMY PROJECT MENU: POTENTIAL INTERVENTIONS IN THE FOUR PILLARS OF THE KNOWLEDGE ECONOMY

(Reproduced with permission from Goel, Koryukin, Bhatia, and Agarwal, 2004.
"Innovation Systems: World Bank Support of Science and Technology Development."
World Bank Working Paper, no. 32.)

I. Policy and Institutional Framework

A. *An appropriate policy, regulatory, and institutional environment* to promote business investment and economic growth driven by innovation:

- Openness to trade and foreign direct investment
- Credit and financial sector policies to deepen financial intermediation
- Judicial systems to improve the rule of law and its enforcement
- Labor markets to be stimulated to create a supply of knowledge workers (including development of conducive labor codes, redundancy regulations, human relations (HR) regulations, and so forth)
- Development of regulations governing distance learning establishments, their accreditation, and supervision
- Conducive environment for public Research and Development Institutions (RDIs) and their staff to engage in contractual research and commercialization of R&D, including appropriate flexibility and autonomy in managing their activities
- Appropriate incentives to stimulate industry (especially small and medium enterprises, SMEs) to develop, adopt, and commercialize new technologies, and promote growth of knowledge-based companies. Such support may include special technology development financing instruments, science parks, reform of public procurement, and other measures
- Appropriate legal framework and business environment for potential investors and particularly for Venture Capital (VC) (including providing a level playing field on tax treatment for VC funds, freedom in selecting appropriate financing instruments, and exempting them from "Blocking Accounts" provisions that could freeze any new investments by VC funds if one of the VC's investments fails (which is usually the case with VC funds)

B. *Domestic competition policy* to promote sustained economic growth and ease the entry and exit of firms into and out of the market:

- Intellectual Property Rights (IPR) regime to align with World Trade Organization (WTO) and European Union (EU) standards
- National competitiveness policy, including antimonopoly regulations and the setting up and strengthening of antimonopoly institutions

- Science and higher education policy to be aligned with the needs of the economy
- Business environment to be conducive to private sector investment in new technological ventures (including appropriate incentives for venture capital)
- Tax and other incentives to improve private sector participation in R&D, including investment in R&D and promotion of knowledge-based companies
- Privatization and liberalization of telecommunications
- Privatization and liberalization of postal services

C. *Support for technology policy* through the setting up and/or strengthening of technology policy institutions to enable them (and to finance some of their activities) to carry out adequate policy studies, conduct foresight studies, serve as data centers on technology issues for private and public sectors both locally and internationally, and carry out technology outreach and public awareness activities.

II. Innovation Systems

A. *Upgrade metrology, standards, testing, and quality (MSTQ) systems* to enhance the competitiveness of the economy and increase trade by aligning the policy, legal, and institutional framework and physical infrastructure with EU and WTO standards:

- Strengthen IPR regime, upgrading the national patent organization's physical infrastructure; improve the quality and speed of services; train patent judges, lawyers, and industry; improve information dissemination
- Improve national standard and quality systems by enhancing the role of the private sector in service delivery; upgrading physical and laboratory infrastructure; improving the quality and speed of services; and reducing costs
- Upgrade metrology services by strengthening national metrology organizations and private laboratories; upgrading metrology facilities and laboratories; improving the quality, number, and type of services; improving awareness among the industry and academic community; and promoting the systems and training users
- Create institutional infrastructure for quality enhancement and certifications, including national quality councils and national accreditation systems

B. *Restructure R&D institutions* to improve the efficiency and quality of research, increase the synergy between the R&D community and industry, and reduce the burden on public budgets. Enhance the benefits of R&D to society by upgrading laboratory facilities and staff skills, modernizing HR systems and business processes, improving marketing and commercialization functions, enhancing the incentives for applied research, introducing competitive research programs, and promoting joint projects with industry and other R&D organizations.

C. *Support firm-level innovation and technology development* to improve the use, adaptation, development, and commercialization of new technologies:

- Strengthen technology financing institutions with private sector participation and build their capacity to provide various types of assistance to knowledge-based companies
- Introduce appropriate financial products to provide low-interest loans, equity, and matching grants to firms for R&D activities and prototype building and for the commercialization of such ideas
- Promote VC funds to provide equity financing (and assistance to entrepreneurs): start-up capital funds to focus on new ventures, and technology funds to support the projects of established companies
- Provide small matching grants for quick technical assistance support for feasibility studies, quality assessments, International Organization for Standardization (ISO) certifications, process improvements, and other noncomplex measures to improve the quality of products or processes and to develop new products
- Support technology and science parks, preferably based in RDIs, to help build synergies with industry by bringing together researchers, laboratory facilities, and private firms
- Set up business incubators and technology service centers to encourage technology-focused new entrepreneurship and to encourage local initiatives to promote SME growth by providing fee-based premises, logistical support, and training

III. Education and Lifelong Learning

A. General reforms

- Modernize the curricula and testing and examination process at all levels to meet the needs of industry and to meet international standards
- Align academic research toward industry needs:
    - Restructure (in some cases establish) education councils and boards to include private sector representatives and sponsors, to ensure alignment with industry needs, and to introduce commercial practices
    - Develop the environment and promote informal learning
    - Improve the research base and integrate with the international community through joint collaborations on publications and projects

B. Qualification assurance and certification

- Create qualification assurance systems to certify individuals and to accredit institutions and firms

- Design national (unified) testing system for higher education establishments, to provide unified requirements for future students, to make admissions more transparent, and to reduce the cost of the admission process

C. Specific assistance to meet training needs

- Provide vocational training through private sector partnerships to meet the demands of the labor market
- Provide retraining for workers to adapt their skills (especially Internet and business and marketing skills) in the rapidly changing environment of the knowledge economy
- Provide training and assistance for redundant employees to reorient them for the job market and to teach new skills
- Provide distance learning (Internet-based education)
- Improve computer literacy and Internet-based skills:
    - Start computer (basic programming and software use) training early in schools and continue into adulthood
    - Connect schools and universities to the Internet
    - Provide vocational ICT training
    - Provide ICT training to enable civil servants to work effectively with modern systems and processes, including e-applications such as e-Procurement, e-Budgeting, and e-Information

D. Education financing products

- Encourage private-sector-driven financing (scholarships, competitive funds, long-term education loans with income-contingent repayment schemes, and so forth)
- Support the public with subsidies, grants, and targeted education vouchers

IV. ICT/e-Development

A. *ICT infrastructure*

- Modernize telecommunications networks
- Promote alternative communication tools (wireless services)
- Improve access to telecommunications (including that of low-income, rural, and other groups—"bridging the digital divide")
- Promote affordable Internet access
- Support creation of a global distance learning network

B. *e-Development applications*

- Intragovernmental interaction: Modernize systems and processes to enhance the communication and information flow within and between ministries and different governmental organizations
  - e-Budgeting—to enhance efficiency and transparency in public expenditures management
- Government-to-business interaction: Create an environment conducive to business, improve efficiency in public spending, and improve transparency
  - e-Registration—to reduce the time taken for and costs of the SME registration process
  - e-Procurement—to reduce costs, strengthen competition, and enhance transparency and thereby to support the participation of SMEs in the public procurement process
  - e-Taxation—to improve revenue collection, enhance transparency, and increase efficiency of the public tax system
  - Digital signatures—to enhance the speed of B2B (business-to-business) transactions and improve the efficiency of business contracting
  - e-Credit information system—to improve the availability to financial institutions of the credit history of borrowers and thereby to enhance the access to finance of SMEs
  - e-Mortgage and pledge registry (of fixed and movable assets)—to improve creditor rights and thereby to enhance financial intermediation in the economy
  - e-Investor—to improve the foreign direct investment (FDI) flow in the economy by serving as the first point of contact for investors, especially foreign
- Government-to-civil-society interaction: Expand access to government information to reduce bureaucracy and inefficiency and to enhance transparency
  - e-Justice—to streamline and automate case handling and reporting systems, and thereby to reduce multiyear backlogs and improve the efficiency of the courts
  - e-Health—to provide access for service providers to vital information and statistics, and thereby to enhance service delivery
  - Land cadastre—to improve access to land records and titles information, to develop land markets, and to improve financial intermediation
- Business-to-business applications
  - e-Commerce
  - Data and information exchange tools for business
- Business-to-client applications
  - e-Services
  - e-Payments (bills, taxes, and so forth)

ANNEX F: MILLENNIUM DEVELOPMENT GOALS AND THE SCIENTIFIC AND TECHNOLOGICAL INPUTS NECESSARY FOR THEIR ATTAINMENT

(Reproduced with permission from Watson, Crawford, and Farley, 2003. "Strategic Approaches to Science and Technology in Development." World Bank Policy Research Working Paper, no. 3026.)

<table>
<tr><th colspan="2">Millennium Development Goals and the S&T Inputs Necessary for Their Attainment</th></tr>
<tr><th>Target and Indicators</th><th>S&T Response</th></tr>
<tr><td>Halve between 1990 and 2015, the proportion of people who suffer from hunger
• Prevalence of underweight children (under five years of age)
• Proportion of population below minimum level of dietary energy consumption</td><td>Increased agricultural research and enhanced food security regimes</td></tr>
<tr><td>Ensure that by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling
• Net enrollment in primary education
• Proportion of pupils starting grade 1 who reach grade 5
• Illiteracy rate of 15–24 year olds</td><td>Improved access to basic education, including science and math education that is built around appropriate curricula and delivered by well-trained teachers</td></tr>
<tr><td>Reduce by two-thirds, between 1990 and 2015, the under-five mortality ratio
• Under-five mortality rate
• Infant mortality rate
• Proportion of one-year-old children immunized against measles</td><td rowspan="2">Increased availability of trained medical personnel and improved access to necessary childhood immunizations and nutritional inputs</td></tr>
<tr><td>Reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio
• Maternal mortality ratio
• Proportion of births attended by skilled health personnel</td></tr>
<tr><td>Have halted by 2015 and begun to reverse the spread of HIV/AIDS
• HIV prevalence among 15- to 24-year-old pregnant women
• Contraceptive prevalence rate
• Number of children orphaned by HIV/AIDS

Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases
• Prevalence and death rates associated with malaria
• Proportion of population in malaria risk areas using the effective malaria prevention and treatment measures
• Incidence of tuberculosis (per 100,000 people)
• Proportion of tuberculosis cases detected and cured under directly observed treatment short course</td><td>Continued research and development into needed vaccines and treatments and improved distribution of available vaccines and treatments for these diseases</td></tr>
<tr><td>Integrate the principles of sustainable development into country policies and programs and reverse the losses of environmental resources
• Proportion of land area covered by forest
• Land area protected to maintain biological diversity
• GDP per unit of energy use (a proxy for energy efficiency)
• Carbon dioxide emissions (per capita)

Halve by 2015 the proportion of people without sustainable access to safe drinking water
• Proportion of population with sustainable access to an improved water source

By 2020 to have achieved a significant improvement in the lives of at least 100 million slum dwellers
• Proportion of people with access to improved sanitation</td><td>Continued research and development of alternative energy sources and enhanced land-use systems, including groundwater management techniques, sustainable forestry techniques, and improved sanitation systems</td></tr>
</table>

EDUCATION DEPARTMENT
HUMAN DEVELOPMENT NETWORK

SCIENCE, TECHNOLOGY
AND INNOVATION THEMATIC GROUP