Science and Technology at the World Bank, 1968-83

by Charles Weiss*

ABSTRACT

The World Bank was an important supporter of science and technology during the period 1968-1983. President Robert McNamara's poverty oriented strategy created challenges that led to technological research, technology assessment and technological innovation in agriculture, forestry, civil works construction, sanitation, and many other fields of development. The Bank also pioneered in financing governmental mechanisms to stimulate industrial innovation. On the other hand, its support to science and technology was limited by lack of an overall policy and systematic support from top management, as well as by cumbersome procedures designed for large infrastructural projects. Even so, its financial independence, its strong leadership, its experienced and non-political technical staff, and its ability to scale up successful innovations through its project lending, made it an important promoter of appropriate technology in the developing world.

The World Bank of the 1970s and early 1980s was a multilateral development assistance agency lending more than a hundred billion dollars at favorable rates to developing countries to finance development projects that otherwise could not have attracted investments from world capital markets. Established by the Bretton Woods Agreements of 1944-5, the Bank was originally intended to finance the reconstruction of Western Europe after World War II.

This is not the usual profile for a scientific or technological institution. Nevertheless, the Bank was an important supporter of science and technology in many forms: research, innovation, education, technology assessment, the choice of technology, technology transfer, technology management, venture capital, science and technology policy, and the building of local scientific and technological capacity. It was a major promoter of the Green Revolution, and of low-cost technology for urban shelter, sanitation, and other infrastructure sectors. It was a major supporter of local research capability in agriculture, and a pioneer in institutional innovation in industrial technology.

The most important stimulus to the Bank's role in science and technology was the announced objective of its President, Robert McNamara, to reduce world poverty.

> "A major part of the [Bank's] program . . . must . . . attack absolute poverty, which exists to a totally unacceptable degree in almost all of our developing member countries: poverty so extreme that it degrades the lives of individuals below the minimal norms of human decency."[1]

McNamara's poverty oriented philosophy transformed Bank lending. To paraphrase and condense the classic words of the Bank's vice-president for projects, the typical loan of the

[1] Robert S. McNamara, "Address to the World Bank Board of Governors," (Nairobi, Kenya, September 24, 1973).

1950s might be a large infrastructure project – say, a power dam – in a middle income developing country, designed and executed by foreign consultants and contractors using conventional, capital-intensive technology and with little attention to social or economic impact; whereas the loan of the 1970s might be for rural development in a low income country, providing an integrated package of goods and services intended to raise the living standards of farmers and emphasizing low-cost design and appropriate technology.[2]

This radical redefinition of objective forced the Bank to confront technical problems that had never been addressed on a world wide scale with its level of financial and professional resources. No one knew how to respond to this challenge. The result was that all Bank staff were encouraged to think broadly and to be innovative. Again quoting McNamara,

> "Neither we at the Bank, nor anyone else, have very clear answers on how to bring the improved technology and other inputs to over 100 million small farmers . . . Nor can we be fully precise about the costs. But we do understand enough to get started. Admittedly, we will have to take some risks. We will have to improvise and experiment. And if some of the experiments fail, we will have to learn from them and start anew."[3]

McNamara was appointed to the Bank after serving as US Secretary of Defense during the Vietnam War, in which the application of high technology had been a conspicuous failure. Perhaps as a result, he was not specifically enamored of technology. On the other hand, he was receptive to technological ideas that could be mobilized in the fight against poverty. Nor were

[2] Warren Baum, "The Project Cycle," Finance and Development (December 1978): 9.

[3] McNamara, op. cit.

most Bank staff oriented to science and technology as a dimension of development. But there were throughout the Bank a solid core of experienced technical professionals, along with a number of individuals who recognized the potential of technological innovation to solve a particular problem that confronted them, and had the energy and entrepreneurial spirit to push their ideas through a complicated but manageable bureaucracy. As the Bank's Science and Technology Adviser, I had the opportunity to encourage and facilitate these innovations, to promote ideas of my own, and to shape overall strategy.

General Background on the World Bank

The World Bank is technically a specialized multilateral agency of the United Nations, with a separate board of directors and an independent source of financing. Its Board of Governors, typically the ministers of finance of the member governments, are represented by a resident Board of Executive Directors, who approve all loans and major policies by a system of weighted voting that favors donor (advanced) nations. (In practice, decisions are taken by consensus and actual votes are rare.) Day-to-day running of the Bank is in the hands of a multi-national professional staff, headed by the president.

The Bank's loans are guaranteed by its member governments. It borrows money on world capital markets at interest rates only slightly higher than those available to the best corporate borrowers, and relends these funds to the governments of creditworthy developing countries at a small profit margin.[4] A sister organization, the International Development Association (IDA), lends to poor countries at highly concessional rates using contributions from advanced countries plus an annual grant from Bank profits. Its staff is the same as that of the Bank.

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[4] The Bank earns additional profits from interest on capital contributions from all member countries, from commitment fees on outstanding loans, and from the returns from active currency speculation.

During the McNamara years (1968-81), Bank and IDA lending commitments increased tenfold, from $954 million in 1968 to $12.3 billion in 1981, and its professional staff increased from 767 in 1968 to 2800 in 1985.[5] This increase was a major McNamara objective, and Bank staff were under constant pressure to meet lending quotas for each borrower country, a goal that he insisted could be met without compromising project quality.

The size of a typical Bank loan was about $50 million, in part because most smaller projects did not justify the Bank's considerable overhead. This lumpiness, while appropriate to infrastructure projects, made the Bank an awkward vehicle that could be used for support to science and technology. Procedures ensuring the quality of projects of this size were reasonably adaptable to the financing of major expansions of national research systems, but were cumbersome when applied to individual research projects or institutions. Except for its budget for applied economic research, the Bank had no fund of grant money for scientific research or other purposes. Instead, it relied on its influence with the UN Development Program, bilateral donors and foundations to raise money for undertakings too small or otherwise unsuited to project loans.[6]

McNamara's anti-poverty program received broad support from the Bank's member governments. At the Board level, the chief political issues affecting Bank policies and practices concerned the lending quotas for politically significant countries (especially Egypt and Zaire), the nationality of senior appointments to Bank staff, the system of procurement, and (in some

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[5] World Bank Annual Reports for 1971 and 1985.

[6] This gap was eventually alleviated by the establishment of the Global Environmental Facility (GEF) in 1991. See the GEF website at http://www.gefweb.org.

cases) recommendations for macro-economic policies to be followed by a country. The Board rarely considered technological issues.

The origin, design, approval and implementation of Bank-financed projects followed a standard pattern known as the project cycle.[7] Once identified, projected were designed ("prepared," in Bank jargon) by consultants chosen by the borrower with the approval of the Bank. These consultants, who usually were based in an advanced country, were thus responsible for key decisions affecting the choice of technology. The project design was eventually translated into lists of goods and services to be procured with the proceeds of Bank loans. This procurement was governed by a system of strict international competitive bidding, intended to ensure that goods and services were purchased at the most advantageous prices, and that vendors in each member country (whose governments were the guarantors of Bank loans) got a fair crack at Bank-financed business. This meant that bidding specifications and procedures had a strong influence on equipment purchased with Bank money and hence on the technology employed for Bank-financed projects.

The bank's operational staff – those directly involved in projects – was an "army of colonels": senior professionals who joined the Bank with 10-25 years of field experience in the sector in which they were employed, and a solid understanding of what had and had not worked in the past, in both developed and developing countries. Leavening the mix were a growing number of "young professionals": smart, young (under 30), ambitious managers-to-be who typically joined the Bank staff with a Ph.D. in economics and a few years of practical experience. These were McNamara's shock troops in the war on poverty, expected to ask the

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[7] Baum, 9.

tough questions and overcome the conservatism of the more experienced but perhaps more jaded professionals.

There is little written about the Bank's overall role in science and technology during this period. The official, two-volume history of the Bank's first fifty years hardly mentions the subject.[8] The main published sources are overviews prepared by the Bank's Science and Technology Adviser to raise the profile of this role and to promote adoption of a science and technology policy for the Bank.[9]

During the period under discussion, the Bank financed projects in nine areas, called sectors: agricultural and rural development, urban development (chiefly low-cost shelter), water supply and sanitation, energy, development finance (government-owned development banks), population, transportation, telecommunications, education and industry. Nutrition and health were added to the population sector in 1978 and 1979, respectively. While there was no science and technology sector as such, technology was an important element of the design of projects in each of these sectors – for example, in the choice of the most appropriate technology, or in the support to the country's scientific or technological capacity.

The Bank's View of the Economics of Technological Development

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[8] Kapur, Devesh, John P. Lewis, and Richard Webb, The World Bank : Its First Half Century (Washington, D.C.: Brookings Institution, 1997): 379-447. The Bank's work in science and technology is mentioned in the chapter on "Agricultural and Rural Development", volume 1, chapter 8, 399-415, and in the chapter by Robert Wade on "Greening the Bank: The Struggle over the Environment, 1970-1995", see especially volume 2, 627-637.

[9] Charles Weiss and Nicolas Jequier, Technology, Finance and Development: An Analysis of the World Bank as a Technological Institution (Lexington MA: Lexington Books, 1984); Charles Weiss, "The World Bank's Support for Science and Technology," Science 227 (1985) 261-265; Paul Shapiro, Technology and Science in World Bank Operations (Washington: World Bank Office of Science and Technology, 1985).

The Bank's support to science and technology is best understood against the background of the economic situation in developing countries at the time. While the world economy was expanding rapidly, creating almost unlimited opportunity for export, most developing countries followed a strategy based on an inward-looking economy.[10] Their overvalued currencies discouraged exports. Their governments set artificially low prices on key commodities such as energy, transport, and fertilizer. This encouraged their use, but led to wasteful and environmentally harmful practices. Local industry was protected from foreign competition by high tariffs and from domestic competition by licensing regimes. Larger industries, often well connected politically, enjoyed favored access to local markets, low-interest loans, foreign exchange and imported machinery.

Rather than maturing into competitive firms, most of these protected industries grew into inefficient, well entrenched and politically powerful vested interests, many a drain on the economy. Taking advantage of their favored access to capital, foreign exchange and raw materials, they used conventional, capital-intensive technology even in countries with low wages and serious problems of unemployment. Smaller industries, lacking political influence, were typically vigorous and labor-intensive, but undercapitalized. They therefore operated well below their potential. Environmental consciousness was low, and regulations were absent or ignored.

The literature on technology and development at the time stressed the need to build up local technological capacity, and to save foreign exchange and protect domestic technology by

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[10] See generally, John Hein,. The World Economy in the 1980s: Trends and Issues (New York: The Conference Board, 1985), report No. 872. The so-called "East Asian tigers" were exceptions to this generalization, and actively encouraged the importation of technology.

regulating the import of technology and machinery.[11] Some developing countries, India being a dramatic example, made major investments in science and technology, founding extensive laboratories and excellent universities, but the immediate effects on the local economy was limited. Local industry felt little need to do research or even to invest in the absorption of technology, and made little use of local sources of research and technology. Local scientists devoted their efforts to maintaining the minimum conditions for research and education, both because this reflected the prevailing value system of scientists world-wide, and because there was little demand in their country for local technology or applied science.[12]

One of McNamara's first acts as President was to recruit a leading development economist, Hollis Chenery, as his economic adviser, and to make economic analysis the basis for policies and for the choice and design of projects, including the choice of technology. McNamara also reorganized the operational staff, teaming technical specialists with economists and generalists, in a "creative tension" that would submit projects to both technical and economic standards. Projects were required to have an expected financial rate of return sufficient to ensure financial viability, and an expected social rate of return sufficient to justify the resources to be consumed, including (at least in principle) environmental and social costs.[13] Bank-financed projects were subject to a separate environmental review to ensure that they did not cause

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[11] Maximo Halty-Carrere, Technology Development Strategies for Developing Countries: A Review for Policy Makers (Montreal: Institute for Research on Public Policy, 1979). Francisco R Sagasti, Technology, Planning, and Self-Reliant Development: a Latin American View (New York : Praeger, 1979).

[12] Michael J. Moravcsik, How to Grow Science (New York: Universe Books, 1980).

[13] Warren C. Baum and Stokes M. Tolbert,. Investing in Development (New York: Oxford University Press, 1985), 425 ff.

unacceptable environmental damage.[14] This collaboration between technical specialists and economists made possible some of the Bank's best work on technological innovation.

The Bank's overall approach to science and technology reflected both the strengths and the limitations of the understanding among development professionals of the role of science and technology. Indeed, the Bank during this period was the major sponsor of research on the applied economics of development. At the macroeconomic level, Bank policy making at the end of the 1960s was dominated by neo-classical economists for whom technology was an "exogenous factor" that required no explicit public intervention. The key to economic development was thought to be creating incentives for efficiency through the package of liberal trade policies, realistic exchange rates, deregulation (especially of administered prices) and support to foreign investment that later developed into the "Washington consensus."

Understanding of the importance of science and technology to economic development was fragmentary at best. It was, to be sure, well known that the classical theory of economic growth could not account for over half of the increase in gross national product actually observed, leaving a "residual" best ascribed to an increase in total factor productivity that was due in part to advances in science and technology.[15] Even so, the preconception of Bank classical economists was that explicit support to scientific and technological development was unnecessary, since this aspect of development, like all the others, would flow from proper economic policies.

By the early 1980s, Bank research economists had recognized the importance of technological competence in the economic development of Korea and the other countries of the

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[14] Wade, op. cit.

[15] Robert Solow, Growth Theory: An Exposition (New York: Oxford University Press, 2000), chapter 9.

Pacific Rim.[16] Building on new theories of technology as an endogenous factor of development, Bank research on the experience of the "newly industrializing countries" (now called "emerging markets") led to the realization that "technological effort" – investments in money and manpower -- was needed even for the choice of technology among existing alternatives for the task at hand, and even more so for its adaptation to local conditions, and eventually for innovation.[17] But the broader understanding that science and technology constituted a critical dimension of overall economic development had to await the advent of the "knowledge economy" of the 1990s.[18]

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[16] Larry E. Westphal, Yung W. Rhee, and Garry Pursell, Korean Industrial Competence: Where it Came From (Washington DC: World Bank Staff Working Paper #469, 1981).

[17] Carl J. Dahlman, Bruce C. Ross-Larson, and Larry E. Westphal. Managing Technological Development: Lessons from the Newly Industrialized Countries (Washington: World Bank, 1984). The idea of technology as an endogenous factor in theoretical models of economic growth began with Richard R. Nelson and Sidney G. Winter. An Evolutionary Theory of Economic Change (Cambridge MA: Harvard University Press, 1982), and Paul Michael Romer, "Dynamic Competitive Equilibria with Externalities, Increasing Returns, and Unbounded Growth," Ph.D. Thesis, University of Chicago, 1983. The impact of the idea of endogenous technology development on development thinking at the time was summarized by Howard Pack and Larry Westphal, "Industrial Strategy and Technological Choice," Journal of Development Economics, 22 (1986) 87-128.

[18] The present view of the role of technological innovation in economic growth is summarized in UN Industrial Development Organization, Industrial Development Report 2002/2003: Competition Through Innovation and Learning (Vienna: UNIDO, 2002). Current World Bank economists have set forth the broadly integrative concept of the "knowledge economy" in Knowledge for Development (Washington: World Bank World Development Report, 1998), Carl Dahlman and Thomas Andersson, eds., Korea and the Knowledge-Based Economy: Making the Transition (Washington: World Bank Institute and OECD, 2000), and Carl Dahlman and Jean-Eric Aubert, eds., China and the Knowledge Economy: Seizing the 21st Century (Washington: World Bank, 2001).

At the project level, Bank thinking in the 1960s reflected the then-conventional wisdom that there was only one efficient technology for any given production process at any given time, and that developing countries should import “off-the-shelf,” capital-intensive technologies from advanced countries. E. F. Schumacher’s “appropriate technology” movement challenged this view, asserting that, between technology that was excessively large-scale and capital-intensive, and technology that was excessively small in scale and hence inefficient, the developing countries needed an “intermediate” technology, a “technology with a human face,” adapted to the economic and social situation in which it was to be applied.[19] Developing countries, he argued, have smaller markets, cheaper labor, lesser educational levels and widespread unemployment that justify simpler, smaller scale and more labor-intensive processes.

To explore the practical feasibility of this approach, Bank research economists, along with colleagues in many countries, collected and analyzed empirical evidence that gradually established that a range of efficient technologies did exist for producing a wide range of industrial products, depending on local conditions.[20] In principle, then, developing countries could choose from a number of alternative technologies for a given purpose. In parallel to this academically oriented research, Bank sectoral specialists developed an approach to appropriate technology that called for defining the problem to be addressed, then searching world-wide for

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[19] E. F. Schumacher, Small is Beautiful: Economics as if People Mattered (New York: Harper and Row, 1973).

[20] Larry Westphal, Research on Appropriate Technology (Washington: World Bank, 1978). Yung Rhee and Larry Westphal, Choice of Technology: Criteria, Search and Interdependence (Washington: World Bank, 1979). Baum and Tolbert, 396-398.

existing technological alternatives, gathering or generating data on their costs and benefits in practical situations, and using techno-economic criteria in choosing the needed technology.[21]

Reflecting McNamara's attitude, the appropriateness of a particular technology to a Bank-financed project resided in its usefulness for the task at hand, not in its innovative character or its level of sophistication.[22] Some problems, as for example the application of remote sensing and geographical information systems, were best addressed by adapting cutting-edge technology to the needs of developing countries.[23] Others were best met by adapting simple technology that poor people could afford, such as cheap, easily maintained hand pumps for village water supply, or providing a service through the use of low-cost labor, as in the recycling of urban solid waste.[24]

In principle and usually in practice, the choice of conventional technology used in a project followed from the application of cost/benefit principles to the project defined during

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[21] Charles Weiss, Appropriate Technology in World Bank Activities (Washington: World Bank, 1976). In practice, the application of such technologies frequently requires organizational, managerial and technological innovation, as for example in the case of the site and services approach to low cost urban shelter. (Herbert Werlin, "Urban Shelter and Community Development", in Weiss and Jequier, 141-155.)

[22] Charles Weiss, "Mobilizing Technology for Developing Countries," Science, 227 (1985), 261-265.

[23] W. Drewes and A. Sirkin, "The Uses of Satellite Remote Sensing", in Weiss and Jequier, 85-102.

[24] Saul Arlosoroff et al., Rural Water Supply Handpumps Project: Handpumps Testing and Development: Progress Report on Field and Laboratory Testing (Washington: World Bank Technical Paper #23, 1984). S. Cointreau, "Environmental Management of Urban Solid Wastes in Developing Countries: A Project Guide." Urban Development Technical Paper Number 5 (World Bank, Washington DC, 1982).

project identification.[25] These techniques evaluated inputs and outputs at world prices, so that technologies using local raw materials or other inputs, including local technologies, received only minor preference. These techniques of cost benefit analysis were constantly refined and elaborated throughout McNamara's tenure. In practice, the application of these techniques tended to ignore considerations that could not be expressed quantitatively, and depended on unavoidable assumptions. They did, however, enable the Bank to reject obvious boondoggles when these were proposed, especially projects using inappropriate technology whose viability depended on subsidies or tariff protection and often actually subtracted value.

In principle, the government of the borrowing country selected the projects it wished the Bank to finance, and was responsible for designing and implementing the project. In practice, except for a few countries (especially India), Bank staff participated actively in concerning and designing the projects it financed. In this way, the design of Bank-financed projects, and the choice of technology used, were the products of a professional collaboration among local project managers, Bank staff and consultants engaged for project design and implementation. The relative contribution of the three depended on the country, the sector and the Bank staff involved.

As noted earlier, foreign consulting firms played a key role in designing Bank-financed projects, and hence in the selection of the technologies they employed. Since these projects were often among the largest being implemented in a given developing country, this meant that foreign consultants played a major role in some of the most important technological decisions in

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[25] **J. Price Gittinger, Economic Analysis of Agricultural Projects** (Baltimore : Published for the Economic Development Institute of the World Bank by Johns Hopkins University Press, 1982). **Lyn Squire, Herman G. van der Tak, Economic Analysis of Projects (**Baltimore: Published for the World Bank by Johns Hopkins University Press, 1975).

the country. Beginning in 1981, the Bank instituted a policy of pressing foreign consulting firms to enter into joint ventures with local firms when designing projects it was to finance. These joint ventures were to be structured so as to provide the local firm with the practical experience they lacked in designing large projects.[26] This policy was broadly supported by the Bank's operational staff and received warm endorsement from its Board of Directors. It stemmed from an initiative by Maurice Dickerson, a British engineer who served as Consulting Services Adviser from 1979-85, and was based on the experiences of Dickerson and other Bank staff engineers in building local consulting engineering capacity, and on surveys of the needs of the local consulting engineering industries in half a dozen developing countries.[27]

Examples of World Bank Support to Science and Technology

The evolution of the Bank's role in science and technology is best seen by tracing the history of a few of the many initiatives undertaken during the period under review. A few, such as those in forestry and low-cost sanitation, succeeded in changing, not only the policy and practice of the Bank, but the values of an entire profession. Others left behind interesting technical papers and pilot projects, but for one reason or another were not widely adopted. Here we will look at projects in agriculture, in infrastructure (civil works construction and low-cost waste disposal), and in industrial innovation.

Agricultural Research, Agricultural Extension and Agro-Forestry

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[26] World Bank, *Handbook on Consulting Service: A Guide for the World Bank Staff* (Washington: Projects Policy Dept., World Bank, 1985). World Bank, *The Use of Consultants* (Washington: Economic Development Institute, World Bank, 1983).

[27] Maurice Dickerson. (interview, November 3, 2004).

Agricultural Research. The Bank supported agricultural research in developing countries in two ways. First, the Bank lent $1.6 billion from 1971-1980 in support of national agricultural research institutions in developing countries, either as stand-alone loans for research or as elements of larger agricultural projects. These projects were justified to Bank policy makers by 35 citations to the econometric literature on the impact of agricultural research on agricultural productivity, almost all of which found economic rates of return above 20%.[28]

Second, the Bank co-sponsored, along with the UN Development Program and the Food and Agricultural Organization of the United Nations, the Consultative Group on International Agricultural Research (CGIAR).[29] The CGIAR was launched in response to a request by the Ford, Rockefeller and Kellogg Foundations, which had responded to the need for improved agricultural technology in what would now be called the developing world, by establishing the laboratories that developed the high-yielding varieties that made possible the Green Revolution.[30] By the late 1970s, these varieties had spread throughout Mexico and the Philippines and had been responsible for dramatic increases in yields of wheat and rice, especially in irrigated land. The three foundations saw the need to apply similar research methods to other crops and to other geographical and agro-ecological regions, but lacked the financial resources for so ambitious an undertaking. Besides, they saw their own role to be that of institutional innovators, and asked the Bank to organize a system capable of mobilizing funds

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[28] T. J. Goering, Agricultural Research Sector Policy Paper (Washington DC: World Bank, 1981), Annexes 3 and 5.

[29] The planning and negotiations leading up to the formation of the CGIAR are summarized in Warren Baum, Partners Against Hunger (Washington: World Bank, 1986).

[30] The first four laboratories to be supported by the CGIAR were the International Rice Research Institute (IRRI, Philippines), the International Center for Corn and Wheat Technology (CIMMYT, Mexico), the International Center for Tropical Agriculture (CIAT, Colombia), and the International Institute for Tropical Agriculture (Nigeria).

for a large and sustainable expansion of the international agricultural research system. To support the CGIAR, McNamara received the specific approval of the Bank's Executive Board for an annual grant from Bank profits to serve as seed money with which to attract large-scale grant funding from bilateral and other multilateral agencies and other sources.[31]

By the early 1980s, the CGIAR counted thirteen international laboratories, each with responsibility for specific crops and agricultural ecosystems, plus a food policy research institute (IFPRI, in Washington DC) and a service for technical assistance to national agricultural research (ISNAR, in the Hague).[32] The Bank's contribution to CGIAR from its profits rose from $8.5 million in 1977 to $24.3 million in 1984.[33]

Research at CGIAR laboratories provided much of the technology used in Bank-financed agriculture and rural development projects, with national agricultural research laboratories adapting this to local conditions. These technological packages typically consisted of improved seeds of high-yielding "Green Revolution" varieties, plus controlled application of irrigation water, fertilizer and pesticide, and were diffused to farmers through the training and visit system (T & V) of agricultural extension developed by Daniel Ben-Or, an Israeli agriculturalist.[34]

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[31] McNamara was reluctant to propose such grants, since they diverted money that would otherwise be transferred to IDA, the Bank's low-interest window. Only two other major grant-financed initiatives were undertaken as a result of direct outside appeals: the Tropical Disease Research Program of the World Health Organization, and the Onchocerciasis (River Blindness) Control Program in West Africa. (See http://www.who.int/tdr and http://www.who.int/ocp).

[32] The CGIAR network now has 16 members. Its current status is summarized on its website at www.cgiar.org.

[33] World Bank Annual Reports for 1977 and 1984.

[34] Daniel Ben Or, James Q. Harrison and Michael Baxter, Agricultural Extension: The Training and Visit System (Washington: World Bank, 1984).

Agricultural Extension. The T&V system consisted of regular biweekly visits by extension agents to so-called "lead farmers," who were chosen to be more progressive that the average in a locality but not so progressive that their practices would be locally regarded as beyond reach. On each visit, the agent provided practical advice and received information about the farmers' problems, which he turned over to the research institutions for solution. T&V greatly improved systems that had previously been badly organized and managed, and had demanded of extension agents many functions unrelated to technical assistance to farmers. It has since been found to be excessively rigid and insufficiently adaptable to local conditions, and is now being replaced by more participatory approach in which farmers actively collaborate with researchers in the selection and trial of new varieties.[35]

We can only briefly summarize the extensive literature on the social and environmental impacts of the major technological changes associated with the Green Revolution.[36] Clearly it made possible increased production of rice, wheat and corn in most of the developing world, especially in places with access to fertilizers, pesticides, and irrigation water, and prevented the widespread famine that had been predicted during the resources scare of the 1960s.[37] Critics have argued that the high-yielding varieties increased the economic and social gap between small

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[35] Robert Tripp, Penniah Sekeram, Derek Byerlee and Larry Harrington, "Farming Systems Research Revisited", in Carl K. Eicher and John M. Staatz, eds., International Agricultural Development (Baltimore: Johns Hopkins Press, 1998). For internal Bank critiques, see World Bank, Agricultural Research and Extension: An Evaluation of the World Bank's Experience (Washington DC: World Bank, 1985), and World Bank, Agricultural Extension: The Next Step (Washington DC: World Bank, 1990).

[36] The economic and environmental consequences of the Green Revolution are reviewed in Gordon Conway, The Doubly Green Revolution (Ithaca NY: Cornell University Press, 1999), 66-81.

[37] Paul Paddock and Mary Paddock, Famine, 1975! (Boston: Little, Brown and Co., 1967).

and large farmers in developing countries, given rise to water pollution and insect resistance due to increased use of fertilizer and pesticides, and failed to increase yields in sub-Saharan Africa.[38]

The consensus of retrospective research is that the income of small farmers did in fact benefit from the Green Revolution, although with a time lag that gave disproportionate benefit to larger farmers that had immediate access to information, credit and inputs, and could afford to take greater risks. The major beneficiaries of lower food prices were actually poor consumers, who spend a disproportionately high share of their incomes on food.[39] In any case, the kind of high-yielding, low impact technology advocated by many of these critics did not exist at the time in a widely useful form, but was restricted to scattered small scale experiments, some carried out by volunteers in non-governmental organizations around the world and some in CGIAR laboratories.

Forestry. The one agricultural technology in which the work of Bank operational staff resulted in direct technological improvement was in social (i.e., small-scale) forestry. Prior to the mid-1970s, the forestry profession in developing countries was largely concerned with industrial forestry: the growing of trees in plantations for the production of wood pulp for paper mills and poles for construction and for utility poles. In response to McNamara's call for projects that would relieve rural poverty, and building on concepts developed by the British colonial service in East Africa and by the UN Food and Agricultural Organization in Rome, the Bank financed a series of highly successful projects in India and elsewhere that enabled small farmers to grow

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[38] For a radical critique, see Vandana Shiva, The Violence of the Green Revolution: Third World Agriculture, Ecology and Politics (London: Zed Books, 1991).

[39] Conway, 44-63.

wood as a cash crop.[40] Largely through the efforts of John Spears, the Bank's Forestry Adviser from 1966 to 1985, foresters and forestry researchers throughout the developing world turned their attention to social forestry as well as to agro-forestry – the integration of trees with agricultural production systems. This led to a major change in research emphasis away from tree varieties and management systems suited to industrial plantations towards those more suited to the needs of small farmers, culminating in the establishment of the International Center for Research on Agro-Forestry (ICRAF, now the World Agro-Forestry Center) in 1979 and the Center for International Forestry Research (CIFOR) in Bogor, Java (Indonesia) in 1993 as part of the CGIAR system.[41]

"Appropriate" Technology for Infrastructure

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[40] Graham Donaldson, John S. Spears, Gordon P. Temple, Theodore J. Goering, and David Dapice, Forestry: Sector Working Paper (Washington DC: World Bank, 1978), 5-11. The lessons of early Bank experience with small-scale forestry are summarized in Staff Appraisal Report. India: National Social Forestry Project (Washington: World Bank South Asia Projects Dept., May 20, 1985), 9-10. Major Bank reviews of its experience with forestry projects are found in Alfredo Sfeir-Younis, Forestry: The World Bank's Experience (World Bank Operations Evaluation Department, 1991) and Uma Lele, The World Bank Forestry Strategy: Striking the Right Balance (Washington: World Bank Operations Evaluation Department, 2000). Bank lending for plantation forestry was sharply reduced in the early 1990s as a result of policy changes driven by environmental concerns regarding biodiversity and water conservation. These policies have been reassessed, and lending is expected to increase. The Bank's current forestry strategy is set forth in A Revised Forest Strategy for the World Bank Group (Washington: World Bank, 2002), and summarized in John Spears, "Sustaining Forests: A World Bank Strategy" (interview, March 19, 2004).

[41] World Agro Forestry, 2004 [online, cited 8 November 2004] Available from World Wide Web http://www.worldagroforestry.org and Center for International Forestry Research, 2004, [online, cited 8 November 2004]. Consultative Group on International Agricultural Research. Available from World Wide Web: http://www.cifor.cgiar.org.

Techno-economic research by Bank engineers and economists made major advances in the understanding of "appropriate technology" in two areas of Bank lending: civil works construction and sanitation. These low-tech areas are of critical importance to poor countries, for whom a more appropriate choice of technology can free resources to provide essential services to a much larger proportion of their population.

Low Cost Sanitation. In 1972, McNamara established an Urban Development Department, charged with developing and launching problems aimed at the urban poor, and named Edward ("Kim") Jaycox, then a rising star among young Bank managers, to head the new department. Jaycox and his staff identified housing as a potential intervention point, and realized that any intervention to improve slum housing would need to address the need for sanitary disposal of human wastes. To the Bank's staff of experienced, western-trained, conservative sanitary engineers, however, water-borne sewerage was the only technology compatible with an acceptable level of public health, and it was up to the Bank and the developing countries to find the money to provide it. To Jaycox and his staff, water-borne sewerage technology was far too expensive and was therefore of limited use.

This difference in philosophy became the starting point for a path-breaking research project. The Bank's newly appointed Water Supply and Sanitation Adviser, John Kalbermatten, a Swiss-trained municipal engineer, realized that previous Bank-financed sanitation projects had served only those urban dwellers who could afford to pay, and that the Bank's new emphasis on helping the poor would require it to try something different.[42] Kalbermatten had become skeptical of the applicability of standard methods of waste disposal in developing countries as a result of his previous experience in Turkey.

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[42] John Kalbermatten, (interview, February 21, 2004).

Reviewing the literature, Kalbermatten discovered earlier papers on on-site disposal of human wastes, an approach that had been abandoned in favor of more "modern" methods.[43] He resolved to see whether more recent technological progress might make it possible to provide sanitary services at a cost that poor people in developing countries could afford. Together with his civil engineering colleague Charles Gunnerson and British economist Dee Ann Julius, he posed the question in techno-economic terms: what is the best level of service that can be provided at a cost compatible with the family income of the population the Bank was trying to serve, and what technology would be most cost-effective in providing that level of service?[44]

With the support of Jaycox, who doubled as chairman of the Bank Research Committee, Kalbermatten and his colleagues won a grant that enabled them to conduct a world-wide assessment of alternative sanitation technologies, ranging from the simple pit latrine to the high-tech "Multrum" system for quick-freezing excreta. This research resulted in a hierarchy of upgradable sanitation alternatives of increasing cost and convenience, beginning with the latrine, advancing to the pour-flush latrine and septic tank, and culminating in the conventional flush toilet. Although most of the existing research on the humble latrine dealt with campsite requirements of American and Western European national parks – information of little use in tropical developing countries -- they found that Rhodesian engineers had invented an "ventilated

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[43] An exception to this generalization is the long-standing work of Bindeshwar Pathak and the Sulabh Sanitation Movement, for which see Pathak, Bindeshwar. 2003. [online, cited 8 November 2004]. Available from World Wide Web: http://www.unwac.org/pdf/Sulabh_Sanitation_Technologies_for_Sustainable.pdf.

[44] John M. Kalbermatten, DeAnne Julius, Charles G. Gunnerson and D. Duncan Mara, Appropriate Sanitation Alternatives, (Baltimore MD: Johns Hopkins University Press, 1982), 3-10, Charles G. Gunnerson, "Sanitation Systems for Developing Countries," in Weiss and Jequier, 125-140, and Baum and Tolbert, 401-404.

improved pit (VIP) latrine" that reduced smells and insect infestations and made this low-cost technology much more attractive.

To demonstrate the validity of this unconventional approach, Kalbermatten obtained funding from the Global Projects division of the United Nations Development Program (UNDP), whose director, the late William Mashler, welcomed the opportunity to increase the impact of his program by collaboration with the Bank. UNDP financed the establishment of a world-wide network of field offices that carried out pilot tests of the new approach and trained local engineers in its implementation. In this they were greatly aided by the global consensus reached by governments at the World Water Conference in Mar del Plata, Argentina in 1977, which (at Kalbermatten's instigation) had announced as its goal that the entire population should be served with adequate water and sanitary services by the end of the World Water Decade that was to begin in 1981. The new approach won widespread approval in developing countries, the Indian government even decreeing that it should be implemented in all villages of less than 100,000 population. A new generation of Bank engineers was receptive to the new approach, which was implemented in a large number of sanitation and urban development projects in many parts of the world.[45]

Labor-Intensive Civil Works Construction. From the beginning, Bank-financed civil works – roads, dams, irrigation channels, and the like – were constructed using the same machinery and capital-intensive methods as are typical in the advanced countries, even in countries with capital scarcity, low labor costs and widespread unemployment. Bank projects in these countries were frequently among the largest in the country, and the failure to employ large numbers of local people was a source of considerable criticism. At the same time, most Bank

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[45] Kalbermatten. (interview).

staff considered that there were no professionally acceptable alternatives to machine-intensive technologies; only bulldozers could produce roads on time and to an acceptable level of quality.

The issue came to a head when the Indian government resisted Bank procedures for international competitive bidding, on the grounds that they discriminated against the labor-intensive methods typically used by Indian contractors. In response, the Bank undertook an extensive project of research on the techno-economic feasibility of labor-intensive civil works construction, carried out by a team of economists and engineers from the Bank research staff.[46] Once opened, the issue of appropriate technology for construction of roads and other civil works turned out to be extremely complicated.

The first issue was that of road standards. While high-speed roads demand high standards and capital-intensive construction technology, smaller feeder roads in developing countries serve relatively light traffic loads and can be built to lower standards.[47] This question turned out to have a profound, albeit indirect influence over the technology of highway construction. Bank researchers realized that the politics of highways led to a systematic over-design, a systematic overemphasis on construction, a systematic neglect of maintenance, and hence a systematic misallocation of resources in this critical and very expensive development sector. They therefore

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[46] A good account of this research is found in Basil Coukis and Nicolas Jequier, "Civil Works Construction," in Weiss and Jequier, 73-82. Fuller technical information is found in World Bank Transportation Dept., Basil Coukis, principal contributor and coordinator. Labor-Based Construction Programs: A Practical Guide for Planning and Management (London: Oxford University Press, 1983), and "The Study of Labor and Capital Substitution in Civil Engineering Construction: Report on Bank-Sponsored Seminars" (Washington, World Bank Transportation Department, 1978).

[47] Baum and Tolbert, 405-406. Thawat Watanatada et al., The Highway Design and Maintenance Standards Model: Model Description and Users' Manual (Washington: World Bank, 1985).

began a major research and technical assistance project on highway design and maintenance, which continues to this day and which has influenced the choice of technology in more than 60 developing countries.[48]

But could feeder roads be built cost-effectively with labor-intensive methods? To answer this question required a major effort to gather primary data on the efficiency of different methods of carrying rocks, earth and other raw materials of civil works construction. This meant looking at such variables as the distance the material was to be moved and the degree of up- or downhill slope; the technologies studied ranged from bulldozers to head baskets to donkeys with panniers. Contrary to expectation, the data showed that at low wage rates, head baskets are actually quite efficient at moving large volumes of earth for short distances on level ground, while donkeys are effective for short distances up steep slopes.[49]

To translate these findings into useful operational guidance required analysis of management procedures. First of all, the large-scale application of labor-intensive construction technology required contractors with experience in managing large numbers of laborers. This experience was common in South Asia but rare in sub-Saharan Africa. Project design therefore had to be augmented to include training in the management of labor-intensive methods. Secondly, procedures choosing among alternative technologies had to be revised to take into account the fact that capital-intensive methods required large outlays for equipment early in a project, whereas labor-intensive projects required outlays for wages spread throughout the

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[48] Clell Harral, (e-mail dated 15 March 2004). For the current status of the highway design and maintenance project, see the websites at http://www.worldbank.org/transport/roads/tools.htm and at http://hdm4.piarc.org/docs/docshome-e.htm.

[49] Baum and Tolbert, 398-399. Weiss and Jequier, 60-61.

contract, thereby lessening their discounted cost. Thirdly, it turned out in practice to be more effective in many cases to pay laborers in food rather than in cash. Fourthly, the productivity of construction laborers turned out to be sensitive to their nutritional status; cheap supplements of iron or vitamins, and medicines for hookworm and other parasites could result in dramatic improvement.[50] Finally, the efficiency of labor-intensive methods was extremely sensitive to the quality and design of hand tools. This finding highlighted the importance of technical assistance to small local manufacturers of shovels, mattocks and similar implements.[51]

The pilot application of the findings of this research to the construction of secondary channels in a Bank-financed irrigation project was a resounding success. Hundreds of unemployed men walked 120 miles across a desert in Chad (Central Africa) to participate in a food-for-work construction program using labor-intensive technology. Originally introduced as a stopgap when the equipment for conventional methods was delayed in arriving, the technology won the support of the Chadian government, the Italian engineers who had won the contract to implement the project in the field, and the Bank engineers supervising the project from Washington. However, proposals for a major follow-on project implementing the lessons of the pilot project petered out when Bank country program officers (who were responsible for meeting lending quotas) realized that to train supervisors would delay the beginning of construction and hence the disbursement of loan funds. In other countries, labor-intensive technology failed to catch on because it was opposed by local engineering staffs, because it did not provide contracts

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[50] S.S. Basta and A. Churchill, "Iron Deficiency Anemia and the Productivity of Male Workers in Indonesia", Staff Working Paper No. 175 (Washington, World Bank, 1974).

[51] World Bank Transportation Dept., Appendix C, 221-257. Baum and Tolbert, 398-401.

for foreign firms, or because it provided insufficient opportunities for payoffs to local officials in foreign exchange.[52]

Industrial Innovation

The idea of a World Bank project in general support of industrial innovation in the more advanced developing countries was initially conceived by the author of this paper in 1971, when he was serving as the Bank's first Science and Technology Adviser,. He was looking for a project that would build broad local capacity for science and technology, and could be considered a logical extension of the projects the Bank was already supporting in agricultural research. He calculated that projects supporting applied research would have a more immediate impact on economic growth than projects supporting universities or basic research laboratories, and would therefore be likely to receive a more favorable reception within the Bank. Weiss' initial assumption was that these projects would take the form of support to government-owned applied research laboratories, which had been established in many developing countries, typically with the support of the United Nations Industrial Development Organization. However, visits to Latin America and Indonesia made it apparent that this model had been a failure in nearly all of the developing countries in which it was tried.

The first Bank mission specifically intended to identify (that is, to delineate and fashion a preliminary design for) a project in support of industrial innovation visited Spain in the fall of 1973, just before the Yom Kippur War in the Middle East, with Weiss as Mission Chief. At the time, Spain was still ruled by the Franco dictatorship, which was then emerging from years of protectionism and was adopting liberal, export-oriented economic policies. Jose-Maria Castane

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[52] Basil Coukis. (interview, January, 2004).

Ortega, Director-General for Industrial Technology in the Spanish Ministry of Industry, encouraged the Bank to help Spanish industry to become more technologically innovative.

The mission found that the problem was not a lack of research, but rather a lack of market-led innovation at the firm level. The failure of Spanish capital markets to finance projects involving technological risk was inhibiting such innovation. This was an important realization, since the role of risk capital in the promotion of technological innovation was then a new idea in developing countries. The senior member of the mission, the late Herbert Hollomon, former US Assistant Secretary of Commerce for Technology, conceived an agency, later styled the Center for the Development of Industrial Technology (CDTI, in the Spanish acronym), that would lend to locally owned firms in support of the research and development of innovative new products. The loans were to be repaid with interest if the product was a commercial success, and forgiven if it was a commercial failure.[53]

This design of CDTI embodied several institutional innovations. First, it supported new product development rather than research. Second, the entrepreneur was free to choose whatever source of technology he wished, forcing the Fondacion Juan de la Cierva, the network of Spanish government-owned applied research laboratories, to compete with other sources of technology, whether foreign or domestic. Third, proposals were judged on the basis of their technological innovativeness and commercial viability, rather than their prestige value.[54] The CDTI project led directly to the formation of Sociedad Espanola de Financiacion de la Innovacion

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[53] Hollomon proposed the agency in the belief that it was a copy of a similar one in Sweden. On the mission's return to Washington, Weiss discovered that no such Swedish agency existed.

[54] Morris Teubal, "Neutrality in Science Policy: The Promotion of Sophisticated Industrial Technology in Israel", in M. Teubal, Innovation Performance, Learning and Government Policy (Madison: University of Wisconsin Press, 1987). Originally published in Minerva 21, (1982) 172-179.

(SEFINNOVA), the first venture capital company in Spain or indeed in any developing country.[55]

CDTI quickly established itself as a source of finance for relatively innovative projects, supporting the development of 123 projects and 33 new products under marketing by 1983.[56] It survived the transition to democracy, as well as several later changes in government, became the Spanish representative to EUREKA and other organizations for technological cooperation under the European Union, and recently celebrated its 25th anniversary. On the other hand, later evaluation found that CDTI had financed only relatively modest adaptations of imported technology, and did not succeed in creating a true research culture within Spanish firms, as Hollomon and his colleagues had hoped.[57]

Considering imperfections in developing country capital markets to be a key obstacle to technological innovation, the Bank undertook a series of projects in support of industrial technology development. In Israel, it financed a program of so-called Projects of National

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[55] SEFINNOVA was formed within the Banco de Bilbao by Juan Moro, who was Executive Director for Spain at the time CDTI was formed and got the idea from the mission that identified the CDTI project. SEFINNOVA was in existence until 1988.

[56] K. N. Rao and C. Weiss, "Government Promotion of Industrial Innovation," in Weiss and Jequier, 38-42.

[57] F. Najmabadi. Bank Lending for Industrial Technology Development: Case Studies of Korea, India, Indonesia, Mexico, Spain and Hungary (Washington DC: World Bank Operations Evaluation Department, 1993), 2 vols. The first generation of successful CDTI proposals financed the local application of well-known technology, supporting the design and development of products like electrocardiograph machines and railroad signaling devices. CDTI was originally intended to be the first stage of a broader Bank-financed program in support of the technological capacity of Spanish small industry, but this idea fell victim to the redirection of Bank lending caused by the increase in oil prices in 1973.

Importance, which provided a 75% subsidy to the development of industrial innovations by Israeli firms, to complement the existing government program of matching grants. The government requested Bank support, less for the money than for the external validation for the stated justification for the program: namely, that Israeli high-tech firms were distant from their natural markets in the United States, and besides tended to neglect the marketing aspects of innovation in the belief that Israeli products were so superior that they would sell themselves. Taken together, the two programs are credited with an important role in launching science-based industry in Israel.[58]

In Korea, the Bank financed the first technologically oriented venture capital company in the country, the Korea Technical Assistance Company (KTAC), as well as a government-owned electronics research laboratory intended to support the technological development of the Korean electronics industry. In the event, the industry grew so fast that the laboratory was privatized within a few years of its establishment.[59] The Korean project was even more successful than its Spanish predecessor, in large part because it was an element of a comprehensive national policy for encouraging industrial innovation.[60]

The projects in Spain, Israel, and Korea served as precedents and models for a series of Bank-financed projects of increasing sophistication in support of industrial technology

[58] Teubal, op. cit.

[59] Najmabadi, op. cit. The expert consultants that advised the Korean government on the design of its industrial development projects were the local managers of the Spanish and Israeli projects described earlier.

[60] Najmabadi, op. cit.

development.[61] For example, in the 1980s and early 1990s, Bank economist Mel Goldman, initiated studies and projects that led to the reorganization and reorientation of government-owned applied research laboratories in a number of countries, including India. Similar projects were financed by the Inter-American Development Bank.[62] A parallel series of projects supported higher education in science and technology, beginning with a $295 million loan to revive and reequip 26 universities throughout the People's Republic of China that had suffered serious damage during the Cultural Revolution. This was one of the first loans to be made to China after it resumed its seat in the Bank in 1980, and was evaluated as an "indisputabl[y] . . . successful undertaking of a task of unprecedented size."[63] Previous Bank loans for science education had mainly financed equipment for science teaching at the high school level and had paid little attention to curriculum or to tertiary education.

Efforts to Establish a Bank-Wide Science and Technology Policy

When he was appointed in 1971 as the Bank's first Science and Technology Advisor, Weiss resolved that the official policy of the Bank should eventually recognize science and technology as an integral part of its accepted mandate. His strategy was to take advantage of every opportunity to promote science and technology throughout the Bank. In practice, this

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[61] For reviews of Bank lending for scientific and technological development, see Najmabadi, op. cit., and Vinod K. Goel et al., Innovation Systems – Science and Technology Development: The World Bank Experience (Washington DC: World Bank, 2004).

[62] For the current IDB science and technology strategy, see Castro, Claudio de Moura,

2000. [online]. Washington: Inter- American Development Bank. [cited 8 November 2004]. Available from World Wide Web: http://www.iadb.org/sds/doc/EDU%2D117E.pdf.

[63] World Bank, "Performance Audit Report: China University Development Project" (Loan 2021-CHA and Credit 1167-CHA), 30 December 1988, 10.

involved conceiving or catalyzing the conception of new policies and kinds of projects, (e.g., industrial innovation, renewable energy, bicycle transport, encouragement of the local consulting engineering industry), encouraging and facilitating ideas developed and championed in other parts of the bank (e.g., remote sensing, labor-intensive waste recycling), and keeping track of scientific and technological initiatives already underway that needed outside intervention.(e.g., labor-intensive road construction, low-cost sanitation).

By the early 1980s, Weiss realized that the absence of an overall policy regarding science and technology was preventing the Bank from taking a more systematic approach to its work in science and technology. Experience had shown that, while Bank staff readily understood science and technology to be important to the sector in which they were personally involved, they did not sense the overall importance of these to development. As a result, each proposed technological innovation had to run a separate gauntlet of Bank officials questioning whether science and technology were really part of the Bank's mandate. Any of the numerous internal reviews to which proposed Bank projects were subject could therefore defeat a useful scientific or technological initiative.

In the hope of building support for a comprehensive policy, Weiss documented in a series of publications the extensive role the Bank was already playing, summarizing the technological content of the typical Bank project of the time, and the early work of the Bank in support of overall scientific and technological development.[64] Building on these publications, he drafted an ambitious 82-page policy paper setting forth all the aspects of science and technology related to the mission of the Bank. Assuming that the Bank would continue its project-oriented lending

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[64] See references in footnote 9.

focused on fighting poverty, he recommended a long-term expansion of the Bank's then-current efforts. The logic of the paper is worth quoting in extenso:

- "Science and technology are central to economic development. . .
- "The technological aspects of problems of developing countries receive insufficient attention. . .
- "Lack of attention to technological problems can have severe consequences. . .
- "The Bank has accomplished much in science and technology, both in promoting research and in developing local scientific and technological capacity. This work includes some of the Bank's most important contributions to development. . .
- "International efforts to support scientific and technological development fall far short of the need. . .
- "The Bank has unique advantages for work in science and technology. . .
- "But compared to its potential, the Bank's current activities are modest. Its approach is unduly cautious and unsystematic."[65]

In support of the importance of science and technology to development, the paper opened with a long list of anecdotal examples demonstrating the "consequences of failure to adopt modern technology and of inattention to research", the benefits of "local capacity applied to local needs," and the possibility of "new technologies for development: some at low cost, using local materials; others from the frontiers of science and technology". The most telling of these examples was the assertion that the "failure to develop improved production technologies for

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[65] Charles Weiss, "Science and Technology and the World Bank of the 1980s" (World Bank, 1982). The bulleted text is taken directly from the headers of the executive summary.

African crops and farming conditions is a central reason for Africa's growing inability to feed itself' – an admission that the Green Revolution had largely failed to reach Africa because of under-investment in local agricultural research capacity.[66]

The report recommended a systematic effort to introduce innovative technology into Bank projects, as well as efforts to build local scientific and technological capacity as a normal element of Bank-financed projects in all sectors. These recommendations represented an intensification of practices that were to a certain extent already taking hold. To codify these practices, however, would have been a major change in the Bank's self-image as a financial institution whose projects used conventional technology and involved minimal technological risk.

At a more fundamental level, the report suffered because the economic theory on which it relied was still fragmentary and provided only the most general support for government intervention in support of scientific and technological development – an important handicap in an organization in which all policies were expected to be supported by detailed economic arguments. In 1982, science and technology was seriously considered as a possible subject of the 1983 volume of the World Development Report (WDR), the major annual publication that serves to announce the Bank's acceptance of a new item on its policy and operational agenda. Science and technology was rejected on the grounds that it was not well enough defined, and Management and Development, presumably a better defined subject, was chosen as the WDR theme instead.

Weiss' policy effort was much less successful than the effort to introduce innovative technology into individual sectors or projects. By the time the policy paper came up for formal

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66 Ibid.

discussion by the Bank's vice presidents, the political situation had changed dramatically from that of the 1970s, both inside and outside the Bank. Ronald Reagan had been elected President of the United States, the Bank's largest shareholder, and "Tom" Clausen, a commercial banker with little development experience or understanding, had replaced McNamara as President of the Bank. The new administration had begun to move the Bank away from its traditional role as a project lending institution toward a greater emphasis on so-called "structural adjustment" loans: large sums of money for budgetary support conditioned on and intended to facilitate macroeconomic reform.[67] Less emphasis on projects meant less emphasis on technology, and still less interest in technological innovation of the sort recommended in the proposed policy paper. The paper was vigorously attacked by Ann Krueger, the Bank's new economic adviser, a "zealot of free trade," on the grounds that governments (and hence the Bank) should not intervene in support of technological development.[68] The proposed policy died.

Perhaps nothing illustrates the status of science and technology at the Bank as a function that was at the same time valued and marginal, and the frustrations of promoting this critical but unappreciated dimension of development, than an incident that took place a few years later. For a few weeks in the spring of 1985, it appeared that the Bank would be "suffering" from an embarrassingly large annual profit. Weiss was urgently enlisted by the Bank's Senior Vice President, Ernest Stern, to draw up plans for a new Foundation for Science and Technology, to be endowed with a substantial sum from these expected profits. The plan called for support to

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[67] Robert Wade, 331-333 and 534-536.

[68] The characterization of Krueger is from Carlos Urzua, "Five Decades of Relations Between the World Bank and Mexico" and Robert Wade, "Greening the Bank: The Struggle over the Environment, 1970-1995", in Kapur et al, 79.

scientific research and technical training on neglected problems specific to the developing world, including collaboration with private industry on technological innovation, then still a novel idea in development circles. The effort died a few weeks later when it turned out that Bank profits would not be as large as had been "feared".[69]

The Bank's systematic attention to scientific and technological innovation as an element of its projects ended in the mid-1980s. The position of Science and Technology Adviser was abolished in 1985, and was revived three years later as part of the Bank's environmental staff at a lower level in the organization. Much of the Bank's technical staff left during the major reorganization of 1987. The idea that science and technology were important to the Bank's work was kept alive: first by Francisco Sagasti, who served as Strategic Adviser to the Bank from 1987-92, and then through the economic research of Carl Dahlman and his group.[70] Despite the lack of interest on the part of top Management, important work on science and technology continued in enclaves within the staff, especially in science education, telecommunications and software, industrial innovation, low-cost sanitation and household energy.

Conclusions

Even at its height, World Bank support to science and technology formed only a small part of its overall operations and consumed an even smaller part of the attention of the Bank's

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69 World Bank profits for fiscal year 1985 were $1.137 billion, substantially larger than previous years but apparently not large enough to cause embarrassment. (World Bank Annual Report, 1985).

70 Dahlman's final contribution before leaving the Bank's research staff to become Resident Representative in Mexico was to enlist the collaboration of the US National Academy of Sciences in convening a meeting that raised the profile of science and technology within the Bank and laid the foundation for the revival of the subject in the late 1990s. See National Academy of Sciences, Marshaling Technology for Development: Proceedings of a Symposium (Washington: National Academy Press, 1995).

management. Yet in the aggregate, the Bank's activities in this area were of considerable scope and magnitude, especially as compared to those of other international organizations and development assistance agencies and indeed to the national efforts of most developing countries at the time.

Although the Bank was not a scientific and technological institution in the traditional sense -- it had no laboratories, and made no research grants -- it had important advantages denied to the traditional science financing agency. The Bank's financial clout and independence, its global scope, its strong leadership, its experienced and non-political technical staff, its relative freedom of action, its skill at techno-economic analysis, its understanding of broad economic policy, its ability to scale up successful innovations, its influence over other development assistance agencies, and the close links between its Bank work in science and technology and its lending operations, made it an important promoter of innovative technology for the developing world. As set forth in the failed policy paper of 1982, the Bank

> "has money, influence, an overview of the problems of development, and concern for social problems. It can build local technological capacity and at the same time involve it in major investment projects. It can finance the scaling up of successful innovations. It can plan and fund large-scale research on critical global problems. It can influence national policies to encourage research, innovation, and more appropriate choice of technology."[71]

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[71] "Science and Technology and the Bank of the 1980s", op. cit.

Recapitulating, then, the Bank did not regard itself as a scientific or technological organization and had no official policy concerning its role in science and technology, seeing this as an adjunct to its investment projects. Most Bank operational staff felt developing countries should use only conventional, well-tested technology, and not assume technological risk, especially not with borrowed money. Attention to more innovative or "appropriate" applications of science and technology was an ad hoc effort led by staff who were champions in their specific fields. The overall result was a record of significant accomplishment, although perhaps well short of what the organization could have accomplished had it made scientific and technological development an official policy objective and institutional focus.

The effectiveness of the Bank's science and technology interventions was limited by its governance and mandate as an international financial institution, its high organizational overheads, the high minimum size of Bank interventions, the cumbersome nature of its operational procedures, and the lack of a grant facility or a fund for scientific and technological research. Its accomplishments fell well short of what could have been done had the Bank operated with scientific and technological development as an official policy objective and institutional focus.

The Bank's diffuse but far-reaching effort to develop technologies suited to the special problems of the poor dwindled sharply after 1985, as the institution shifted its focus to macroeconomic policy and away from development projects. Even so, important work continued in enclaves within the staff, although without support at the policy level. This work made an important contribution in its own right, and provided a base for the revival of interest in science and technology in the late 1990s. More than a decade passed before the revolutions in information technology and biotechnology propelled science and technology to something of its previous prominence in Bank work -- in a very different World Bank, under a different World Bank President, with a different science adviser, and indeed in a very different world. But this is a subject for a different article.

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