Technology Policy for Sustainable Agricultural Growth

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Introduction

MARK W. ROSEGRANT

Technological progress in agriculture is crucial for alleviating poverty in developing countries. It is essential to overcoming the constraint on food production growth imposed by limited land resources. Expansion of employment opportunities for the poor, and hence a permanent solution of the poverty problem, is virtually impossible in most developing countries without technological innovation.

But, although scientific advances are clearly the most important precondition for technological progress in agriculture, such progress also depends on appropriate policies, particularly in the developing world environment. At the early stages of economic development, policies are needed that provide the appropriate socioeconomic, institutional, and infrastructural backdrop for efficient development, dissemination, and use of new technologies.

The International Food Policy Research Institute's research on technology policy, which examines how public policies on technology can influence the potential for improvement of agricultural productivity, is divided into four areas: (1) agricultural research and the development and dissemination of new technology, (2) investment policies, (3) policies to encourage the use of productive inputs, and (4) pricing policies. It is increasingly oriented to assessing whether agricultural production technologies are appropriate to the physical, social, and economic environments of developing countries. And, although new technologies are essential for agricultural productivity growth, it is also essential that the growth they engender be sustainable and that any adverse effects on the environment be minimized.

In July 1990 in The Hague, IFPRI held a seminar on "Technology Policy for Sustainable Agricultural Growth." The policy briefs collected here, prepared for that seminar, aim to identify the roles of research, infrastructure, credit, and pricing policies, as well as policies to encourage the efficient development and utilization of inputs such as irrigation, fertilizer, and improved seed varieties. They encompass a wide range of policies that taken together contribute to an overall technology policy for stimulating sustainable agricultural growth in developing countries.

Agricultural Productivity Growth and the Structure and Organization of Agricultural Research

PETER ORAM

Agricultural research is crucial to the development of sustainable new techniques of agricultural production that are appropriate to the physical, social, and economic environments of developing countries. Thus it is encouraging to note a considerable expansion of international and national support to agricultural research during the last two decades. This can be attributed partly to the successful development and widespread use of the high-yielding varieties of rice and wheat since the late 1960s, and to the related establishment of the Consultative Group on International Agricultural Research (CGIAR) in 1971. This new and successful venture in international assistance has been accompanied by increased international and bilateral donor support to agricultural research, and also by expanded government research efforts in the developing countries themselves.

As a result of these global developments, agricultural research expenditures in and on behalf of the developing countries have tripled since 1970 in real terms and now exceed $2 billion. The number of scientists in developing countries has been accelerating, increasing 35 percent during 1970-75, 30 percent during 1975-80, and 52 percent during 1980-85. In total, the number of researchers now exceeds that in Western Europe, North America, Japan, and Oceania combined, although their level of training is generally lower and funding per scientist varies greatly.

This expansion represents significant progress toward creating a strong base for technological change, but it should not be regarded with complacency. The balance between food supply, employment, and population growth remains precarious; experimental yields of some major staple crops seem to have reached a ceiling, and unprecedented stresses created by human activity unpredictably threaten the global environment. Thus new demands will be made on research while existing pressures continue.

On the supply side, much remains to be done to strengthen agricultural research capability. Analysis of the current status of national systems in developing countries reveals widespread problems. While some of these can only be tackled successfully by individual countries, they collectively pose a challenge to the international research community as a whole.

CURRENT PROBLEMS

Although the growth in numbers of scientists has been impressive, it has been rising more rapidly than research funding, leading to a disproportionate expenditure on salaries and diminished availability of funds for operational purposes. In addition, research resources are significantly skewed. Seventeen countries, each having 1,000 or more researchers, compose 83 percent of all developing-country agricultural scientists; of these 78 percent are located in Asia, but in all regions except Sub-Saharan Africa, national agricultural research systems (NARS) with more than 1,000 scientists represent 60 percent or more of all agricultural research staff. Conversely, there are about 45 countries with less than 50 scientists, mainly small countries in population and economic resources, located principally in Sub-Saharan Africa, West Asia, and the Caribbean and Pacific. They represent about a quarter of all developing nations. How to help them cope with their agricultural problems is a difficult challenge.

The share of national wealth allocated to agricultural research by many developing countries is still well below the normative 1985 target of 1 percent of agricultural GDP recommended by the 1975 World Food Congress, or the 2 percent advocated by the World Bank in 1980. Some of the largest countries in area and population are spending less than 0.5 percent of their agricultural GDP, whereas several small countries spend more than 1 percent. However, when the relative strength and flexibility of the NARS in the large countries is compared with the lack of a critical mass of personnel in the small countries, it cannot be said that the latter have more effective systems, even though they are spending more per capita on research. Most other normative criteria for judging the effectiveness of research systems are equally flawed. Recent work by ISNAR shows that large errors in comparing expenditures across countries can result from different methods of currency conversion. This is an important area for policy-oriented research.

The same comment applies to criteria for determining research priorities as a means of allocating resources to agricultural research. Various scoring and weighing systems have been devised, and some are being used, but they tend to rely heavily on subjective judgments, while other approaches such as congruence analysis are biased against commodities of low current value even though they may have a high potential. Most approaches are more useful for determining commodity priorities than for allocating resources to farming systems, environmental, or social science research. Ongoing work on improving methodology therefore merits close international attention.

The quality of scientific staff is extremely uneven, with a

majority only having a first degree. Although the proportion with a domestic master's degree is rising, many countries depend heavily on overseas training for Ph.D's. Only 16 out of 90 countries for which data exist have more than 20 percent of staff trained to the level recommended by the World Bank for 1990.

There is a serious shortage of trained computer, laboratory, engineering, and maintenance technicians. Few countries have more than one per scientist, and facilities are generally poor for training technicians. So is their status: university graduates do not generally seek employment as research technicians, although a bachelor of science degree is desirable in many technical fields.

There are serious gaps in disciplinary coverage. A study of 15 countries of West Asia and North Africa by the author shows that there is a heavy emphasis on crop improvement (especially plant breeding, pathology, entomology, and nutrition), with considerably less resources being devoted to land and water resource management, engineering, postharvest technology, and marketing; social sciences; and animal sciences, where improved nutrition and management are accorded lower priority than veterinary science. Data for other regions collected at IFPRI and not yet published largely confirm these findings. Whether to continue to reinforce current strengths or to adopt a gap-filling approach, geared to meeting future priorities, is a difficult decision for research directors, since the latter is likely to require changes in overseas training priorities as well as in domestic university curricula and admission policies.

Universities in developing countries are often poorly linked to the NARS, both with respect to their teaching policies and their research programs. Joint studies to determine future demand for trained personnel are the exception rather than the rule, nor is there follow-up on graduate employment as a guide to policy. Universities are commonly in the Ministry of Education, whereas NARS are in the Ministry of Agriculture, but this should not serve as an excuse for lack of collaboration. As the demands of research become more exacting, closer cooperation between NARS and the universities will be essential. Any tendency by agricultural universities or by research institutes to operate an agricultural "closed shop" is likely to be self-defeating: a broader base of science (biotechnology, ecology, climatology, hydrology, agroforestry, and economics) will be required in the future if sustainable increases in productivity are to be achieved.

The private sector has yet to play an effective role in agricultural research in most developing countries. Government policies have often discouraged private initiative; hence even when they are dramatically reversed, as in Bangladesh since 1988, there may be a void. It is important that governments seek to capitalize on the comparative advantage of the private sector by offering incentives to research investment (for example, in livestock, horticulture, forestry, or input use), while not withdrawing support from public-sector research institutions to undertake tasks less attractive to private enterprise, such as the improvement of self-pollinated staple food crops, agricultural diversification, farming systems, and speculative research on developing areas of apparently low agricultural potential.

The latter presents thorny problems. Much depends on whether the potential is intrinsically low because of major environmental defects (such as flooding, aridity, salinity, or topography), or because of remoteness, lack of investment, low population density, or controllable diseases. It is difficult to argue that an unpromising area should be given priority in the allocation of research resources merely for social reasons: other solutions should be sought for social problems that agricultural research is unlikely to be able to solve. Where there is an apparent potential, but one that may require major investment for its solution (in infrastructure, irrigation, drainage, sponsored migration, and human services, for instance), economic analysis should be applied to assist research policymakers in deciding how much and what type of resources to allocate.

Decisionmaking with respect to regional allocations of resources can be enhanced by agroecological characterization and the establishment of geographical information systems. This can provide the basis for developing an effective national network of regional research stations and on-farm trials, as has been the case at the state level in India. The greater precision this offers for matching research resources to regional potential and for effective transfer of technology to producers should help to lift agricultural productivity above its plateau of the late 1980s, especially in Asia. However in establishing regional stations, it is essential to give strong backing to outposted staff: morale problems often arise because staff feel at a disadvantage technically and socially and when it comes to promotions, compared with headquarters staff.

Most senior managers in NARS lack professional training in management. This paradox is largely the result of hierarchical systems of promotion. Not only does the approach to selecting research directors need to be based more on qualifications and performance rather than merely on seniority, but a specific effort needs to be made to train potential leaders in the techniques of management. Where countries lack schools of management, donors should give priority to training their potential managers overseas.

Bureaucratic constraints beyond the control of research managers hamper flexibility, prevent timely disbursement of funds, delay program implementation (for purchase of equipment, for example), restrict freedom of choice in promotions and appointments, and generally cause problems for which management may be unfairly blamed. Such difficulties are not always understood by donors or even by national policymakers, and although there is no universal remedy, they are a potent source of frustration and inefficiency.

In part, these problems stem from the weak links that often exist between research managers and policymakers. It is essential for the successful adoption of technological innovations, that technology policy be closely linked to national policy, both to ensure that research is aligned to national priorities, and to keep policymakers informed of the measures needed to stimulate adoption of promising research results. Failure to achieve this dialogue and to create an awareness of the value of research may jeopardize financial support to the NARS. Unfortunately, senior research staff generally lack training in policy analysis, and even when they possess it, their position in the bureaucratic hierarchy may deny them direct access to national policymakers.

Procedures for the evaluation of the output of agricultural research are relatively weak, particularly those related to the socioeconomic effects of research. This is a problem that neither the international centers nor the NARS have

fully resolved. Continuing international study is required of methodologies and procedures for impact analysis, and for mechanisms to provide feedback from the impact analysis to the research process.

Transfer of promising new technology to farmers is impeded by poor linkages between research and extension services, by weakness of extension training and methodology, and by deficiencies in supply of seed, fertilizer, and other inputs. Little research on extension techniques and their effects seems to be under way, although IFPRI's work demonstrates the important role of infrastructure in making new knowledge and input supplies available. Nor have many governments developed effective partnerships with private enterprise in technology transfer. As agriculture becomes more diversified (an important national objective in a number of countries), the scope for private-sector involvement in research and its diffusion should increase.

At the international level, the CGIAR system has come of age structurally but is grappling with difficult decisions concerning the admission of new institutes from a number established outside its orbit, often by the same donors, to deal with problems that were perceived as not being adequately covered by the CGIAR centers. Several of these are of an environmentally oriented nature. The CGIAR also has to come to terms with the upstream-downstream problem: how far to move from its predominantly middle-of-the-road applied research focus toward more basic scientific research, on the one hand (especially biotechnology), and toward research on adaptive and farming systems, on the other. At the latter level, controversy exists concerning the priority that should be given to "low-input" research and lower potential areas.

CONCLUSIONS

- Although commendable progress has been made since 1970 in developing a global research effort to attack agricultural problems of the tropics and subtropics, much remains to be done, especially at the national level.
- Although the 17 countries with large research systems contain almost 3 billion people (77 percent of developing-country populations), there are 65 small countries with fewer than 100 scientists. How can global research resources best be mobilized to help these small countries? Networking is one possibility, but where national systems have less than 25 staff members, they may be unable to participate effectively. Could the larger developing countries do more to help, perhaps in partnership with CGIAR centers or developed-country neighbors? The Australian Center for International Agricultural Research in the Pacific is an example of this approach. What sort of help is most appropriate?
- For all developing countries, but particularly for larger countries, greater emphasis needs to be placed on raising the quality of scientists and management skills and providing adequate operating funds and technical support. Efficiency rather than mere growth in numbers should be the main goal.
- There needs to be carefully planned reallocation of resources to rectify the widespread imbalances among commodities and among disciplinary areas of research, and training programs and university priorities must be realigned accordingly.
- The two ends of the research spectrum need to be reinforced. NARS are often staffed predominately by agricultural scientists who lack expertise in the basic biological and physical sciences. Without this expertise, it will be impossible to solve difficult environmental problems or to capitalize on the potential of biotechnology, on which great hopes are being placed. NARS must cooperate more closely with the universities and with the private sector in such research.
- Decentralization of research regionally and to the farm level, based on agroecological characterization and on an interdisciplinary systems approach, offers the most effective solution to diagnosis of the agricultural potential and provides the essential feed-in and feedback mechanism to upstream researchers and to policymakers. Regional stations are also an appropriate location for linkages to extension districts and for research on new approaches to technology transfer. Their key role in the research system must be supported by high-quality staff and operating resources.
- Linkages between research managers and national policymakers must be strengthened and the former trained in management techniques and policy analysis.

These conclusions have important implications for donor and center training policies. Not only does heavy weight need to be placed on raising the proportion of graduates, especially Ph.D staff, but shifts in priorities appear desirable to meet future research needs and to improve systems management.

A number of methodological and evaluative issues have been raised here that have important policy implications. Enhanced research to find solutions would be widely beneficial. Within the CGIAR system, IFPRI and ISNAR should probably be working more closely on this aspect of research.

Development of National Agricultural Research Systems in an International Quantitative Perspective

PHILIP G. PARDEY AND JOHANNES ROSEBOOM

The pattern of global investments in agricultural research has undergone dramatic changes during the last two decades. The system as a whole has grown substantially, while developing countries have significantly increased their share of the installed agricultural research capacity within the public sector. However, in a marked departure from this overall pattern of growth, recent trends, particularly with regard to financial support for agricultural research in developing countries, show some potentially disturbing signs of slowing.

RESEARCH PERSONNEL

Averaged over 1981-85, the global total of agricultural researchers working in the public sector stood at just over 100,000 full-time-equivalent researchers (Table 1). This represents close to a twofold increase in the number of public-sector agricultural researchers since 1961-65, which translates into an annual growth rate of 3.2 percent. During this period, the number of researchers grew fairly uniformly across all developing regions, at 6.3 percent almost four times the rate of the developed countries (1.6 percent). As a result, the global share of researchers in developing countries increased from 24 percent in 1961-65 to 45 percent in 1981-85 (Figure 1). The Asia and Pacific region accounted for 49 percent of the developing-country total in 1981-85 (Table 1). About 20 percent of the developing country-researchers resided in the Latin America and Caribbean or the West Asia and North Africa regions, whereas Sub-Saharan Africa accounted for the remaining 11 percent. Including South Africa in these regional figures would increase the number of researchers in the 1981-85 total for Sub-Saharan Africa by about 39 percent and more than double the number of scientists in the region who hold postgraduate degrees.

Table 1
Agricultural resesarch personnel and real expenditures, developed and developing countries.

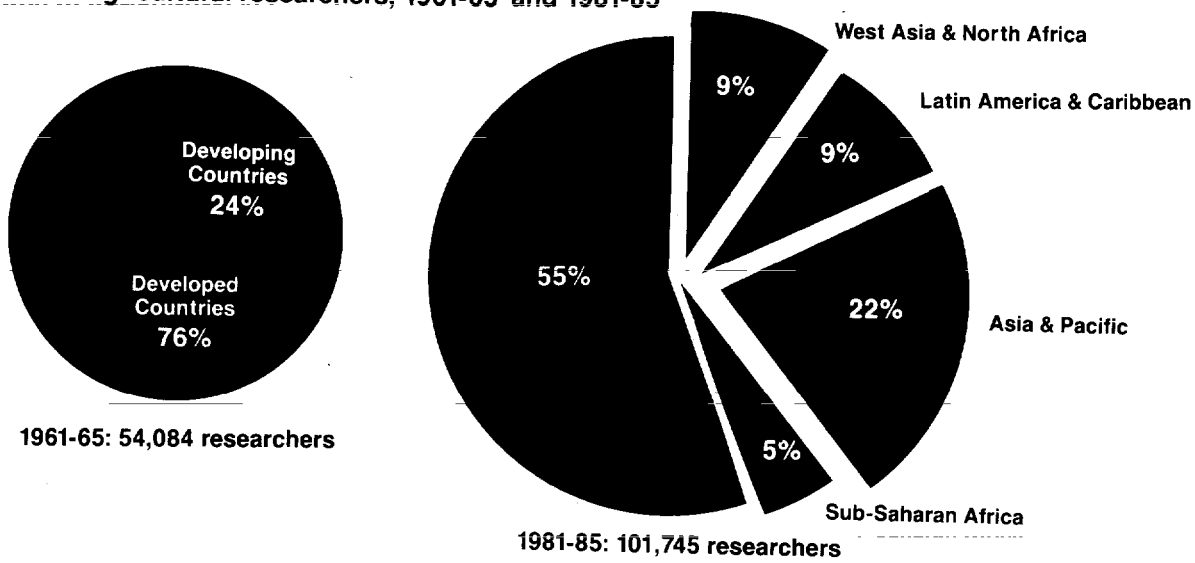
Country Group	1961-65	1966-70	1971-75	1976-80	1981-85
Agricultural researchers (fulltime equivalents)					
Developing countries	12,787	18,929	25,440	35,095	45,513
Developed countries	41,297	44,424	47,726	51,253	56,233
Total[a]	54,084	63,353	73,167	86,348	101,745
Agricultural research expenditures (constant 1980 PPP $million)					
Developing countries	822	1,307	1,716	2,308	2,696
Developed countries	2,191	3,057	3,726	4,172	4,785
Total[a]	3,013	4,365	5,442	6,480	7,481
Real expenditure per researcher (constant PPP $)[b]					
Developing countries	64,300	69,100	67,400	65,800	59,200
Developed countries	53,000	68,800	78,100	81,400	85,100
Total[a]	55,700	68,900	74,400	75,000	73,500

Sources: Philip Pardey and Johannes Roseboom, ISNAR.

[a] World totals, due to data limitations, exclude the USSR, Eastern Europe, China, Mongolia, North Korea, Vietnam, Cambodia, Djibouti, Bhutan, South Africa, and Cuba.

[b] Figures represent weighted averages rounded to the nearest hundred dollars.

Figure 1
Regional shares of agricultural researchers, 1961-65 and 1981-85



RESEARCH EXPENDITURES

Global spending on public agricultural research averaged $7.5 billion in real expenditures in 1981-85, up by a factor of 2.5 in two decades, compared with 1.9 for research personnel. The developing countries' share of expenditures grew from 24 percent in 1961-65 to only 35 percent in 1981-85, considerably less than their share of the world's agricultural researchers (45 percent) (Figure 2).

Comparative patterns of growth in research personnel and expenditures are presented in Figure 3. While the 6.1 percent rate of increase in real spending for developing countries as a group was approximately 50 percent larger than real spending increases for the developed countries during 1961-85, it fell marginally short of the 6.3 percent increase in research personnel experienced by the developing countries. By contrast, the developing countries increased their real expenditures at approximately double the rate of their research personnel.

The period-to-period averages in Table 1 reveal a general contraction in financial support for agricultural research in the developing countries during the final period of the sample. The precipitous decline in the rate of growth in real spending for Sub-Saharan Africa reflects a widespread slowdown throughout the region, compounded by a 23 percent decline in total spending by the Nigerian system, which alone accounts for about one-quarter of public spending on agricultural research in Sub-Saharan Africa. Anecdotal evidence suggests that this contractionary pattern of support for public-sector agricultural research has continued or even accelerated in many developing countries and may even have spread to some of the developed countries.

Figure 2
Regional shares of agricultural research expenditures, 1961-65 and 1981-85

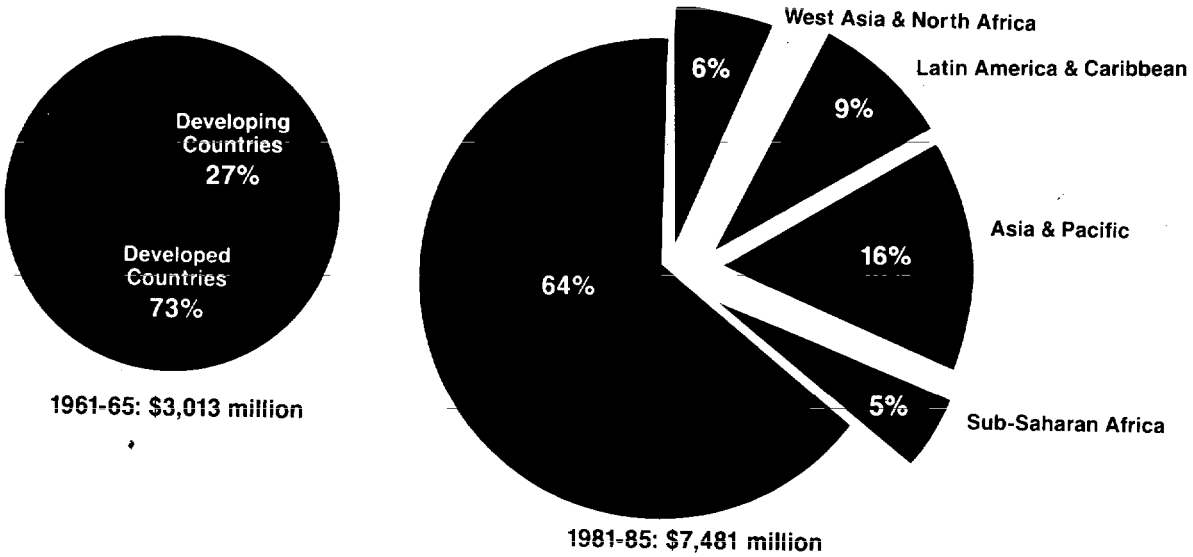
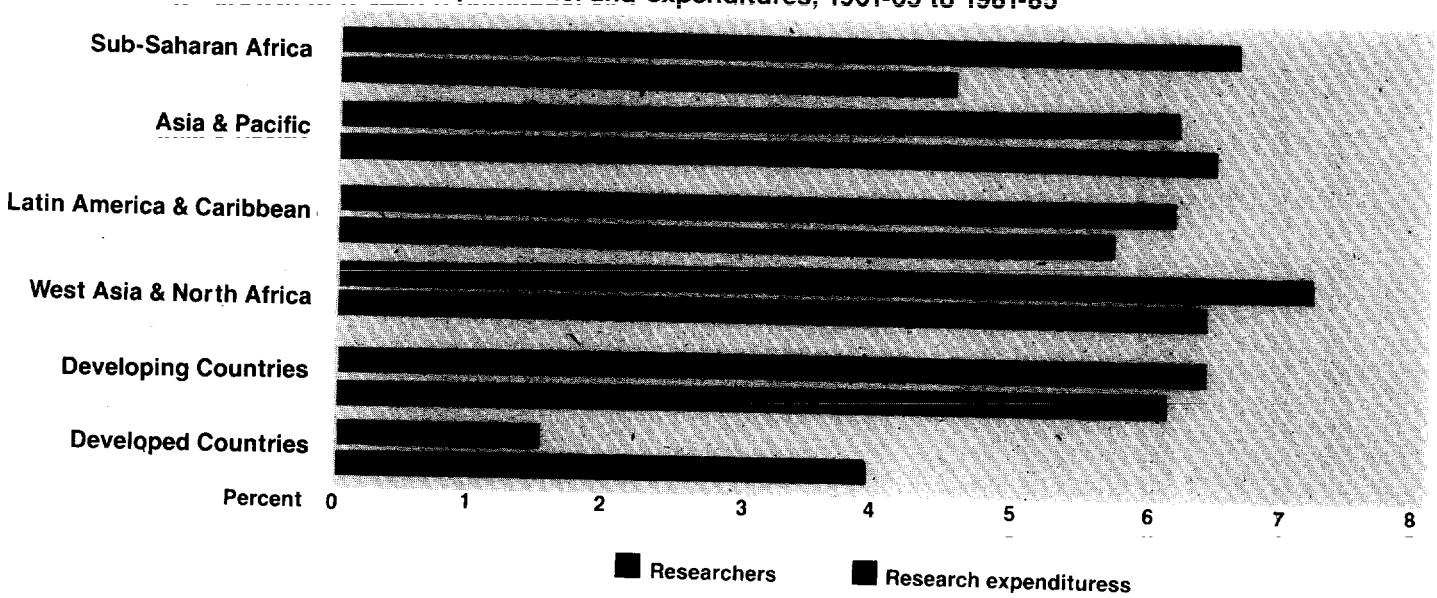


Figure 3
Annual average growth of research personnel and expenditures, 1961-65 to 1981-85



SPENDING PER SCIENTIST

Comparative indicators of real expenditures per researcher are also presented in Table 1, with real expenditures measured in 1980 purchasing power parities (PPP) rather than in annual average exchange rates, in order to translate expenditures measured in nominal local currency into real aggregates, thus allowing for cross-country differences in relative price levels. The overall spending-per-scientist ratio for developed countries increased steadily from $53,000 in 1961-65 to $85,100 in 1981-85. Thus, the developed countries as a group moved steadily toward more capital-intensive—both human and physical capital—research systems. Detailed data from the U.S. state agricultural experiment stations on the changing factor mix of their research systems point to a significant increase in human rather than physical capital during this period. By contrast, the developing countries spent $64,300 per researcher in 1961-65—some 21 percent more per researcher than the developed countries—which peaked during the early-to-mid-1970s, followed by a steady decline to $59,200 by the 1981-85. Moreover, the pattern of growth in spending-per-scientist ratios among developing countries is rather uneven.

The overall decline in labor productivity and stagnation in land productivity that has characterized Sub-Saharan agriculture since the early 1970s somewhat belies the growth in research personnel and real expenditures. Distortionary government policies that accelerate the transfer of resources out of agriculture and bias public-sector infrastructural investments in favor of urban over rural areas have played a role here as elsewhere. However, the sustained and substantial decline in ratios of spending per scientist since the early 1970s—which spread to 65 percent of the region's national agricultural research systems (NARS) by 1981-85—may provide clues to some additional causes of this productivity paradox. The rapid growth in the region's cadre of researchers has been realized through large increases in the number of relatively inexperienced, and hence less expensive, nationals. Expatriate ratios have dropped from 90 percent or so in the early 1960s to about 29 percent on average in 1981-85, with the limited evidence available suggesting that during this period 60 percent of the region's researchers had less than six years of research experience. Moreover, the region's NARS are especially reliant on donor-sourced funds—estimates place the donor share during 1981-85 at 36 percent—and, as a consequence, staffing decisions tend to be decoupled from expenditure decisions. Personnel decisions are made largely within the context of a domestic policy environment often constrained by civil service regulations, while expenditure levels and priorities must also respond to the various agendas of multiple donor agencies. In such an environment, it is difficult to harmonize personnel and expenditure allocations that maintain an appropriate factor mix (such as labor, capital, and support services), as well as desirable remuneration and incentive structures that stabilize attrition rates, particularly for the more skilled researchers within a national research system.

The Asia and Pacific region displays an erratic and barely perceptible drift upward in real spending per researcher from historically low levels, compared with other regions. These low levels persist even after factoring in the region's relatively low average prices. Indeed, the translation procedures used in this research substantially increase, in fact double, the region's share of the global volume of resources committed to agricultural research compared with other research. Economies of scale and scope accruing to the large research systems that dominate the Asia and Pacific figures tend to lower average costs per unit of research output and in turn account to some extent for the region's lower spending per researcher. In addition, lower labor service costs, resulting from a comparative abundance of labor, would induce a substitution of labor for capital and other inputs in the knowledge production process, also driving down the region's ratio of spending per scientist.

Average spending per scientist for the Latin America and Caribbean region as a whole was relatively stable during 1961-75, increased during the late 1970s, largely in

response to gains by the larger NARS within South America, only to show a widespread and substantial decline throughout the region in the early-to-mid-1980s. This decline was driven as much by stagnating expenditure levels as it was by a rapid growth in research personnel, which, given the austerity measures facing many countries, will pose continuing problems for these NARS.

SIZE OF NARS

The average size of public-sector NARS has increased from 358 to 674 researchers. In 1961-65, there were 74 NARS that employed less than 25 researchers; by 1981-85 that number had declined to 39. During the same period, the number of NARS employing more than 1,000 researchers increased threefold. Nevertheless, there still exists a substantial number of NARS with little capacity to undertake anything but highly focused, generally adaptive research on a few commodities or to maintain search and screening capabilities on a slightly broader front in order to capture potential research spillovers.

Cross-country research spillovers arise through various channels, ranging from technology transfers by private seed, machine, and chemical companies to formal and informal networking structures among public-sector NARS. Success in capturing these potential spillovers in a timely manner continues to elude many of these small systems, according to a recent study by Thorpe and Pardey of agricultural knowledge transfers among Southern Cone NARS. As expected, the smaller NARS within the region tapped regional and international sources of scientific knowledge at a somewhat higher rate than the larger systems, but it was especially revealing to observe that the currency of their knowledge sources declined dramatically over time.

SUPPORT FOR NARS

Securing and maintaining domestic political support for the public-sector component of NARS and translating that into financial support for agricultural research is a fundamental issue confronting all national research policymakers. Agricultural research intensity (ARI) ratios, which express expenditures on public-sector agricultural research as a proportion of agricultural product (AgGDP) are commonly cited measures of the support afforded NARS. The data in Table 2 show an approximate doubling of ARI ratios for both developing and developed countries during 1961-85. These data also confirm the positive correlation between income levels and ARI ratios noted by earlier observers, with ARI ratios for high-income countries approximately double those of low- and middle-income countries.

However, a potentially more instructive approach to understanding the structure of support for agricultural research is gained by placing publicly funded research in the context of the overall level of public support for agriculture. The relative research expenditure (RRE) ratio in Table 2 represents the proportion of total public expenditure on agriculture that is spent on research. It thus provides an indication of the relative importance given to research on agriculture within the constraints imposed by overall public spending on agriculture. Clearly the income-linked pattern of support for agricultural research that many have implied from an inspection of ARI ratios is far less evident in the RRE data. While cognizant of the general assertion that governments in low-income countries tend to discriminate against agriculture (whereas high-income countries discriminate in favor of agriculture) these data, at least for the present, leave open the question of whether policymakers in poor countries give lower priority to agricultural research than those in rich countries, within the overall constraints of spending on agriculture. More fundamental limitations to increased public support for research in low-income countries may well lie in the financial and political constraints imposed by overall and agricultural-specific levels of public-sector spending. Much more analysis is needed to understand the (political economy) forces that shape the support for NARS and to give policy guidance that duly recognizes such constraints.

To achieve sustainable or continued agricultural growth and productivity gains, while at the same time addressing the externalities or social costs that accompany the development process, requires a sustained and focused effort on the part of national agencies that generate and transfer technology. Governments have a clear role to play in choosing policies that give farmers the incentives to make socially desirable capital and technological investments that enhance productivity while making effective use of private and public resources that are committed to generating these technologies.

Table 2
Agricultural research intensity and relative research expenditure ratios

Income Class (Number of Countries)	Agricultural Research Intensities			Relative Research Expenditures
	1961-65	1971-75	1981-85	1981-85
Low (29)	0.30	0.40	0.66	8.5
Lower-middle (28)	0.49	0.69	1.00	9.5
Middle (18)	0.47	0.58	0.84	8.7
Upper-middle (18)	0.59	0.82	1.26	8.3
Low and middle (93)	0.45	0.60	0.91	8.8
High (16)	1.03	1.82	2.37	11.3
Total (109)	0.49	0.69	0.85	9.2

Source: Philip Pardey and Johannes Roseboom, ISNAR.

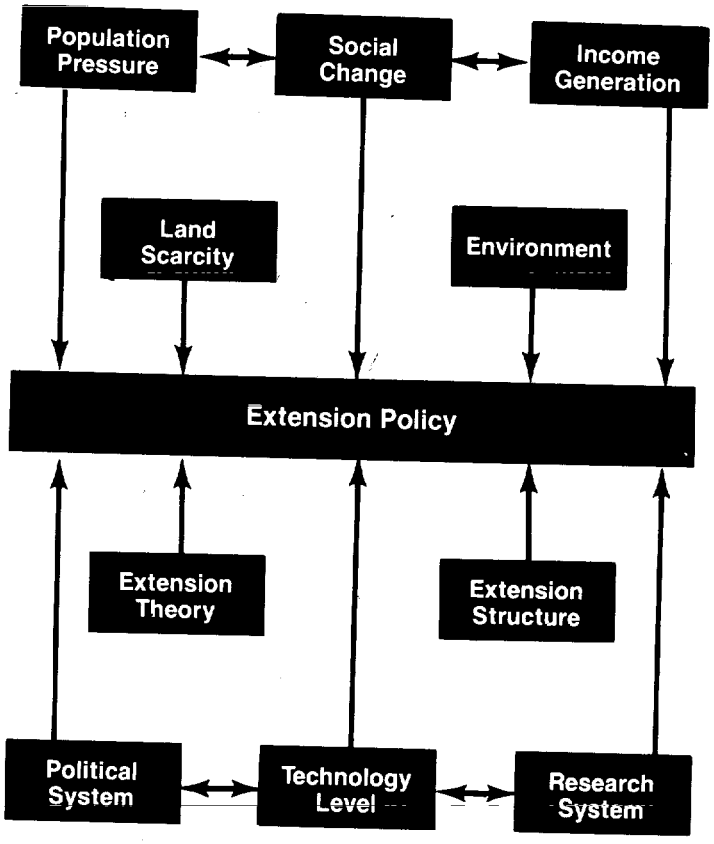
Agricultural Extension and the Diffusion of New Technologies

H. U. THIMM

In many developing countries one may observe a paradoxical situation where the increasing supply of new technologies meets decreasing acceptance by small-scale farmers. More and more techniques are available; fewer people learn to make use of them. An analysis of possible causes leads to five important questions, which are addressed in this brief.

Figure 1 indicates the most important factors shaping extension policy. This brief concentrates on some basic issues of rural development related to the use of modern technologies by small-scale farmers. In answering these questions, the author's own experiences and results of various studies in the field are called upon to explain, at least partly, the paradox.

Figure 1
Factors shaping extension policy in developing countries



1. Does the increasing complexity of modern technologies hinder the transfer of knowledge through the extension system?

New technologies do not immediately solve the farmers' problem of low income. On the contrary, they usually add to his debt burden. The questionable necessity of introducing new technologies with the help of credit programs turns a farmer into a debtor without guaranteeing future income. The farmer has to cope not only with a new technique, but also with a completely new enterprise system, characterized by commercial inputs, monetary expenditures, and changing market conditions. The complexity of modern technology is not the main problem; the complex situation in which the farmer is supposed to use them is.

Extension services are apparently ill-equipped for transferring the necessary knowledge to farmers to cope with this complex situation. Too many times the small farmer is treated by the extension officer as a sick patient for whom a doctor is prescribing medication. The extension agent is not a doctor but a partner in a mutual consultation process, in which new technologies are, perhaps, part of the problem-solving activity.

Traditional transfer of knowledge from the research system to the farmer is bound to fail, because most of the time the conditions for successful implementation are not met on the farms as they are on experiment stations. Many new technologies do not fail because they are wrong but because the conditions under which they are used are different from those under which they were developed.

If these observations are right, the main remedy for productivity gaps in small-scale agriculture is a change in the extension approach to fit the real world of family farmers. The flow of information has to be turned upside down! A transfer of information to the research system about the complexity of the small farm is urgently needed. If that is done sufficiently, the complexity of modern technologies does not represent a threat but a chance to properly select the right technology for each particular situation in a dynamic development process.

This model advocates a bottom-up flow from agriculture to research, as opposed to the traditional top-down flow of information from research to agriculture. Feedback from the farmer to the research system becomes the major task of the extension service.

2. Do extension concepts reflect the growing interaction between modern technology and the environment?

Extension concepts rarely reflect the growing interaction between modern technology and the environment. This is partly due to the general neglect of environmental prob-

lems in the past in industrialized and developing countries alike. It is also partly due to the specific neglect of the small farmers' environment. Experiment stations usually do not recognize the farmers' environmental problems. A predominately "top-down" knowledge flow therefore does not include environmental issues, especially not those created by modern technologies. The task is twofold: first, to identify clearly environmental threats such as erosion and overpopulation at the farm level, and second, to include environmental components whenever research activities are initiated.

The controversial discussion about the training and visit (T & V) extension system has revealed quite clearly that success or failure of extension programs will depend to some extent on the method used for the transfer of knowledge. In countries where the supporting infrastructure is available for substantial production increases, a crop- (or livestock-) oriented extension approach is appropriate and will show fast results. In many other countries where the lack of supporting infrastructure is a major factor limiting production, a farmer-oriented extension approach will be more appropriate. Whereas, in the first case, the extension service may be used to push production campaigns, in the second case, its foremost task is to assist the farmer in solving his own problems under the existing conditions. The crop approach gives priority to the desired product and recommends practices developed under controlled conditions. The farmer approach takes the farmers' restrictions more seriously and places more emphasis on the risks involved in using modern technologies.

3. Are alternative agricultural extension methods needed for specific country situations?

Extension approaches have to be differentiated to reflect varying country situations. Strategies that focus on individuals (master or progressive farmers) may work better in some countries where the cultural background favors hierarchical order and obedience. The same holds true for the T & V system, which may fit a number of Asian countries, but not all. Strategies that focus on a group farming environment, however, will perform better in many African countries where group consensus and infrastructural deficits prevail. In a 1983 study V.A. Sigman and B.E. Swanson asked 59 directors of national extension organizations about the major problems they face. In low-income countries, the lack of sufficient training was ranked very high; in the middle-and higher-income countries, lack of mobility and organizational shortcomings were mentioned first. In the first instance, extension messages have to match the low level of staff expertise. It has to be recognized that in most countries the extension workers who are in direct contact with farmers are the least trained, the lowest paid, and probably the least motivated people. In the second case, why create and develop sophisticated results at research stations if organizational gaps and lack of mobility are reducing the potential of the extension service to do a proper job? Farmers with limited access to inputs in Africa and Latin America will need a different type of support, possibly including input provision, compared with farmers in countries where inputs are available and extension staff have to convince farmers to avoid overinvestment and too frequent changes in technology.

4. How can a higher degree of integration of research, extension, and education be accomplished?

The reasons for demanding a higher degree of integration of research, extension, and education are obvious, but how should this be accomplished? Based on lessons learned in industrialized countries, a consensus has been reached that raising the general level of education will widen the acceptance of modern technologies. Therefore, education is treated as a fixed precondition for applying research and extension. The need for a stronger tie between research and extension grows with the complexity of technologies and their application on family farms. The more that information flows from the bottom up, the more the need exists to conduct joint field trials for farmer verification with the extension services and with research stations. A 1983 study in the United States ranked feedback from extension staff as 20th out of a possible 21 criteria that research scientists use in selecting problems for research. This may be acceptable in an industrialized country, but it is absolutely wrong in a developing country where research solutions may determine whether small farmers under marginal conditions live or die.

5. How should public funds be optimally allocated between research and extension?

The optimal mix of public funds devoted to research and extension in a developing country will change over time. The direction of change depends on the level of economic development, historical structures, political priorities, and external aid programs. In addition the share of research and advice that is being supplied by commercial companies selling inputs is important. Do institutes in the CGIAR system already substitute for national research? Two broad types of historical development can be seen. In the first, research (mainly for cash crops) has historically been introduced by colonial or commercial interests, and extension has played a minor role for obvious reasons. With the shift of national research activities to include food crops, the number of potential users is widening and the need for more public extension expenditures grows. In the second type, a country where little national research has developed, the extension service is used mainly to disseminate external research results. In this situation, the extension service will need to obtain and allocate relatively more resources to screen external results for internal use and to close the gaps that exist because of specific country circumstances.

In summary, three major tasks stand out.

- Integrated planning of national research and extension packages is required to create awareness of the need for an efficient technology transfer flow and an optimal mix of budgetary funds for proper operation.
- A strictly sectoral implementation of research and extension programs is advocated to achieve the most efficient performance, with a goal-oriented organizational structure capable of fast "bottom-up" information flows.
- Regular interdisciplinary evaluation of each research and extension package to allow final judgment about the benefits of new technologies at the farm level is necessary.

Infrastructure and Agricultural Production

RAISUDDIN AHMED

Development of rural infrastructure, as a component of agricultural development, is a subject that normally falls outside the purview of a government department of agriculture, yet, as shown in this brief, it is critical for agricultural production. However, before discussing infrastructure substantively, it is necessary to define it in order to establish a common ground for discussion.

What is infrastructure? Albert Hirschman's four conditions for distinguishing infrastructure from other productive assets provide a useful guide: (1) the services provided by the activity are necessary to facilitate, or are in some sense basic to, the carrying out of a wide variety of economic activities; (2) the services are provided in almost all countries by public agencies or by private agencies subject to public control, and they are provided free of charge or at rates publicly regulated; (3) the services cannot be imported; and (4) the investment needed to provide the services is characterized by "lumpiness". Consistent with these conditions, IFPRI's research, particularly the results presented in this brief, focuses on rural transport and communication, electricity, markets, and financial institutions. Transport, communications, and electricity are considered to be the hard-core elements. It has been observed that transport and communications are closely associated with the development of electricity, markets, and financial institutions in rural areas.

INFRASTRUCTURE AND AGRICULTURAL PRODUCTION

The effects of infrastructure on the diffusion of modern technology, the profitable combination of inputs and outputs, and the prices of inputs and outputs result in high productivity in agriculture. These effects are generated in a variety of ways. First, development of transport and communication infrastructure reduces the costs and time required for moving people and information. The resulting increase in interaction with the outside world and the informal education process that such interactions involve help change attitudes and values and contribute to human capital development. The effect on motivation has immense implications for economic progress because people are motivated to turn a profit, not just to subsist, and their capacity to perceive and to seize comparative advantages is enhanced. These types of changes make rural structure propitious for diffusion of modern technology and ideas.

Second, marketing of modern inputs such as fertilizers, pesticides, and irrigation equipment is logistically easier and cheaper in infrastructurally developed areas than in underdeveloped areas. Agricultural extension workers find it convenient to work in places where they can move easily and live comfortably. Installation and servicing of irrigation equipment such as tubewells are feasible and less costly in areas where infrastructure is developed.

Third, both factor and product markets operate more efficiently in infrastructurally developed areas. And penetration of institutional credit is deeper. Where infrastructure is more developed, easier access to markets facilitates production of labor-intensive perishable products such as vegetables, fish, and livestock.

Empirical studies on infrastructure are not numerous, but significant evidence is available to corroborate the relations described above. Table 1, from a recent study on Bangladesh by Raisuddin Ahmed and Mahabub Hossain, indicates the nature and extent of the difference in diffusion of agricultural technology between developed and underdeveloped villages. It shows clearly that the intensity of use of modern technology—high-yielding varieties (HYV), irrigation, and fertilizer—is about twice as high in developed villages. Analysis of the role of infrastructure in this process of diffusion indicates that installation and repair of private tubewells, electrification, and availability of fertilizers are extremely dependent on the presence of good roads and

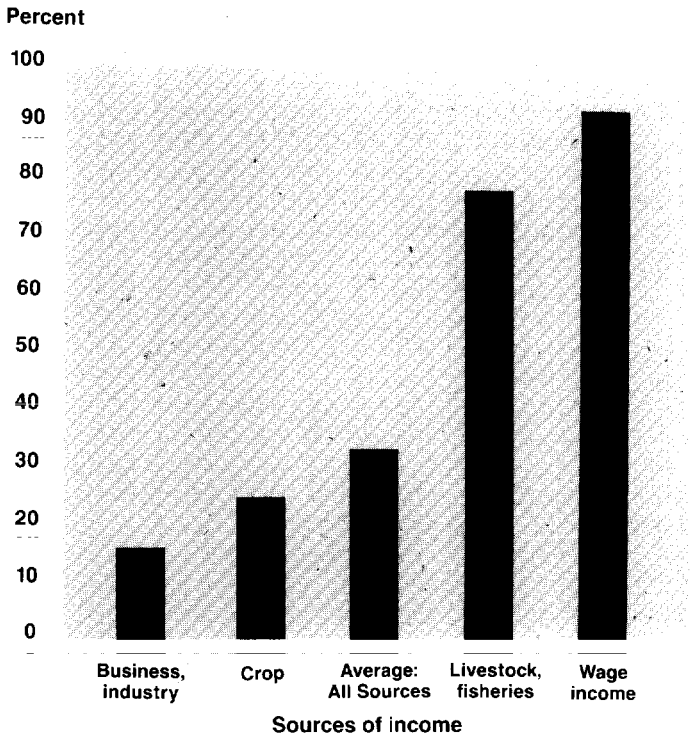
Table 1:
Differences in the use of modern technology and price levels between developed and underdeveloped villages in Bangladesh, 1982

Item	Unit	Underdeveloped Villages	Developed Villages	Percent Difference
Irrigation	Percent of owned land	20.50	42.10	105
Area under HYVs	Percent of cropped area	24.50	42.00	71
Fertilizer	Kilogram of material/hectare of cropped land	78	150	92
Labor	Man-days/hectare	115	119	4
Paddy price	Taka/maund	151.19	154.07	1.9
Rice price	Taka/maund	276.73	293.80	6.2
Fertilizer price	Taka/maund	138.60	119.34	-13.7
Labor wage rate	Taka/day	18.06	20.19	11.8

Source: R. Ahmed and M. Hossain, IFPRI, forthcoming.

markets. Figure 1, from the same study, shows that although the increase in household income from all sources as a result of infrastructural development averaged only 33 percent, income from perishable products such as livestock and fisheries increased by 78 percent and wage income increased by 92 percent.

Figure 1
Summary of infrastructural effects on household income



Source: Ahmed and Hossain, IFPRI, forthcoming.

Although comparable studies are quite rare in Asia, a recent study by Binswanger in India has shown that the combined effects of roads, markets, and financial institutions on agricultural production is greater than the individual effect of irrigation development. Although India has invested heavily in large-scale irrigation projects, a major part of total irrigated area has still come from private tubewell irrigation, which spread mostly in infrastructurally developed areas.

Another study, by McGuirk and Mundlak, based on district-level data from 1960-79, found that the adoption of HYVs and private irrigation methods was positively related to the amount of roads in the Indian Punjab. The average long-run output elasticity of the road constraint on total agricultural production was 0.44 in that study; in 1964 the output elasticity of the road constraint was zero, whereas by 1979 it had risen to 1.10. As construction of roads relaxed the constraint, the output elasticity increased. A study in the Philippines by Evenson shows the output elasticity with respect to road density (measured in miles of road per 1,000 hectares of land) at 0.32. This implies that if road density is increased by 100 percent, agricultural production will increase by 32 percent.

In an African context, a simple comparative study by Devres of farmers in Malawi found that farmers near a road used two-and-a-half times more oxen, fertilizers, and plows than farmers away from the road. Nearly 40 percent of farmers near the road made cash farm expenditures for production, whereas only 12 percent of farmers farther away made such expenditures.

POLICY IMPLICATIONS

Everybody knows that infrastructure is important. But, the critics say, unless it can be proved that it is more important than other public expenditures, a case has not been made for increased allocation of public expenditures to development of rural infrastructure. Further, the critics argue that rural infrastructure makes the poor poorer, increases corruption, is wasteful in the absence of supplementary measures, cannot be maintained, and degrades the environment. Most, not all, of these allegations are popular notions without any systematic evidence. Such views may have caused the sharp decline in allocations to infrastructural investment by multilateral lending agencies such as the World Bank during the last two decades. They may also be the underlying cause of the sharp declines in allocations of public resources to infrastructure once urban-oriented development has reached saturation and development is extended to rural areas of developing countries.

Ideally, if it were possible to estimate cost-benefit ratios of all conceivable public projects and then rank them accordingly, it would be possible to see how infrastructural projects fare in comparison with each other. Even then, the results would largely depend on how the multifaceted and indirect effects of infrastructure were taken into account, the basis for which has always been weak. For example, in a study of rural roads in Bangladesh, Chowdhury and Hossain found that the internal rate of return (IRR) of such roads, including their carefully measured production effects, is 45 percent compared with general estimates of IRR (based on a guess on the production effect) of 14 to 24 percent for projects in the Planning Commission portfolio.

In reality, no developing country uses cost-benefit analysis for sectoral allocations, even though use of the cost-benefit ratio of an individual project or of technical alternatives for a project is widely practiced. Allocation to infrastructure is based on experience and judgment about current or emerging bottlenecks. The "bottleneck" approach should be replaced by conscious creation of excess capacity that will, in turn, induce production of agricultural and nonagricultural goods, services, and employment. Political decentralization, development of local governments, revenue sharing, and delegation of authority to mobilize resources at the level of local governments are critical conditions for development and maintenance of rural infrastructure.

Concern for environmental degradation in development of rural infrastructure is valid. But it should also be realized that infrastructure has the potential to serve as a powerful weapon for preserving the rural environment. Local governments, which are necessarily involved in rural infrastructure, can protect and develop community property, roadside trees, and other rural environmental projects. Adequate drainage provisions in road construction can reduce flooding. Most important are the income-generating effects of rural infrastructure. The rural poor are less likely to undertake deforestation activities if they have other sources of income.

Irrigation Investment for Sustainable Agricultural Growth in Asia

MARK W. ROSEGRANT AND MARK SVENDSEN

Since the mid-1960s the growth rate of irrigated area in the world has declined by about 60 percent; in Asia, it has declined by 72 percent. Asia nevertheless accounted for nearly 90 percent of the total area irrigated in developing countries in 1985. Because of the dominance of Asia in developing-world irrigated area, this brief will focus on Asia. Many of the conclusions, however, may also be relevant for irrigation policy in Africa and Latin America.

Accompanying the decline in the growth rate of irrigated area has been a sharp reduction in irrigation investment, which is likely to further slow the rate of growth in area irrigated. Aggregate irrigation investment in Asia by the four main financial donors for irrigation development—the World Bank, the Asian Development Bank, the U.S. Agency for International Development, and the Japanese Overseas Economic Cooperation Fund—reached its peak in real terms (US$1,443 million per year) in 1977-79, and by 1986-87, was about 50 percent of the 1977-79 level. The reductions in investment have resulted from the relatively favorable food security situation in Asia and consequent low grain prices, the large public and foreign debt loads carried by most of the countries in the region, the increasing real costs per hectare of new irrigation development, the declining share of unexploited irrigation development, and concerns about the environmental implications of irrigation projects.

The sharp investment decline also points to more general questions regarding the long-term contribution of irrigation development to sustainable agricultural productivity growth. The issue of irrigation and sustainable growth has at least three key aspects. The first issue is the development of an appropriate policy framework governing the investment necessary to sustain required agricultural productivity growth. The second issue relates to policies affecting the sustainability of the irrigation systems themselves. The third is the set of interactions between irrigation and the broader physical environment.

IRRIGATION INVESTMENT AND LONG-TERM PRODUCTIVITY GROWTH

Decisions to invest in irrigation infrastructure are made in a climate of conflicting perspectives. At a basic level, there is the difficulty of predicting the pace and direction of technological development and formulating a complementary strategy for irrigation development.

Even within a broad strategy of irrigation development, annual decisions frequently are inconsistent. As relatively long-term investments, with 30-to-50 year operating lives and substantial salvage value, it might be assumed that the decisions would be strongly influenced by long-term trends of need and potential benefit, with short-term circumstances being significantly less influential. Thus, one might expect the decisions to be made in a manner similar to that for other basic utilities, such as roads and power, which would permit relatively steady development, reasonably predictable effects, and stable employment patterns for irrigation-related skills. In those countries with formal development plans, such as India's Five-Year plans, irrigation-sector planning does have a development infrastructure approach.

However, individual projects associated with the plans are subject to cost-benefit evaluation (as well as political calculus) which frequently alters the regional distribution, scale, and pace of implementation of projects and usually introduces a shorter time perspective in the decisionmaking. Although careful cost-benefit analysis tries to place the estimation of costs and benefits in the appropriate time frame, the difficulties of predicting the future and the pressure of present circumstances tend to introduce a bias toward consideration of short-term economic conditions. Changes in short-term world rice prices appear to have a particularly large influence on irrigation investment decisions, playing a major role in investment declines such as occurred in the 1980s.

The most costly consequence of investment decisions based on shorter time perspectives is excessive variability in investment patterns that induce high variability in growth rates in agricultural production, particularly for key food crops such as rice. The cyclical pattern of investment and production further exacerbates domestic price variability, creating uncertainty for farmer production decisions, threatening the nutritional status of the poor, and increasing the costs and difficulties of other policies designed to maintain stable growth.

At a second level, short-term decisionmaking increases the difficulties for irrigation agencies in making institutional and organizational adjustments and causes relatively large variations in demand for irrigation planning, design, and construction supervision skills. The boom-and-bust cycle resulting from the excessive influence of short-term fluctuations on investment decisions leads to shortages of skilled labor and professional expertise at construction time and crash training programs, followed by retrenchment and layoffs.

The need to be economic and efficient in the allocation of development resources is obvious. Whether traditional cost-benefit analysis is the most appropriate mechanism for making these types of decisions is arguable. A "value engineering approach" that places greater emphasis on sustained efforts to satisfy the agricultural output objectives contained in a longer-term plan should be evaluated. This, combined with a more stable pace of sector development, would tend to smooth the cycles in investment and production, reducing the potentially high costs of excessive variability and leading to easier assimilation of the new

capacity and more appropriate human resource development within the agencies and in the support sectors.

SUSTAINABILITY OF IRRIGATION SYSTEMS

A second major issue for sustained irrigation development is the sustainability of the functioning of irrigation systems themselves. A number of studies and evaluations have highlighted problems of shortfalls in area served by irrigation systems, lower than expected productivity, drastic overuse of water where available, allocational disparities between farmers at the head of the system and those at the end, large recurrent cost burdens on government, and overrapid system deterioration and the need for frequent system rehabilitation. Sustainability in this sense is an issue that profoundly affects not only the viability and productivity of existing systems but the economic rationale for the development of new irrigation areas as well. To address this seemingly disparate set of problems at the policy level, two main sets of interrelated remedies have been proposed—reforms of basic managerial structures and incentives and of water pricing policy.

To improve system organization and management in a fundamental way, it is necessary to reassess the basis on which irrigation agencies operate, raise their revenues, assess their institutional performance, reward and promote their staff, and share responsibility with farmers. Interesting recent evidence from the Philippines and Sri Lanka, as well as several recent cross-sectional studies on irrigation system cost recovery, suggests that there currently exist viable organizational models for placing public irrigation systems on a more self-sustaining footing, decreasing costs of operation, increasing revenues from direct beneficiaries, and providing incentives for more effective management on the part of irrigation bureaucracies.

A key factor in these reforms appears to be establishment of links between the two major participant groups in the irrigation enterprise—public irrigation departments and farmers—which create stable mutual expectations regarding policies and management. Irrigation agencies must play a leading role in this, but cannot be expected to carry out all of the specialized study, training, and advisory functions themselves. Thus sustainability at the system level is an institutional problem that includes the irrigation agency, farmers, and supporting organizations.

One of the key policy instruments generally advocated in the package of management reforms is volumetric pricing of irrigation water delivered to farmers. Charging for irrigation water on a per unit basis will theoretically induce farmers to economize on the use of water, eliminating waste and increasing crop production. And, it would likely increase the share of irrigation costs paid by farmers, improving the financial viability of irrigation systems or agencies.

However, the efficacy of volumetric water pricing may be limited for the reservoir and diversion systems that make up a large proportion of Asian irrigation. In these systems, water is paid for by its users on an administratively determined basis, often a flat user charge or a rate related to farm size. Water is usually delivered on a continuous flow or rotational basis, and the farmer has little or no control over the volume or timing of deliveries. In such a situation, volumetric pricing may have no incentive effect.

Moreover, the cost of developing and administering a system for volumetric pricing for this type of irrigation may be much larger than the cost of improving control and timely delivery of water supplies. The costs (in both manpower and hardware) of implementing and administering an improved system to allocate water quantities optimally are likely to be much lower than the costs of measuring water use and enforcing volumetric charging to individual farms. For diversion and reservoir systems, improvements in water management and deliveries seem to offer greater net benefits than volumetric pricing.

In tubewell irrigation systems, however, volumetric pricing of water should be much more cost-effective than quantity allocations. The price of water can be readily determined from the cost of pumping water, and monitoring of the pricing system through volume of water pumped or duration of pumping is relatively inexpensive. Privately owned tubewell systems that sell water generally use volumetric pricing. It would be appropriate for publicly held tubewells to do the same.

IRRIGATION AND THE RESOURCE BASE

A third set of issues relates to the interactions of irrigation schemes with their environments. Included here are the effects that related systems in upper watersheds, such as livestock and agroforestry, have on irrigated agriculture downstream, as well as the negative external effects that irrigation development and operation may have on populations and resource bases. Both types of effects degrade physical resources that are finite and can lead to serious discontinuities in benefit streams and cut short the productive lifetimes of major infrastructural investments.

Of all of the undesired consequences of large-scale irrigation development, salinity and waterlogging are probably the ones most frequently mentioned in the context of irrigation system sustainability. Estimates of their extent around the world vary, but they constitute a major and undeniably serious threat to the productive capacity and long-run sustainability of some irrigation systems.

Engineering solutions may be necessary in some situations, but technical constraints are usually not, in fact, the most intractable ones. To the extent that waterlogging and salinity stem from overirrigation, which is the major causative factor, the institutional and management measures outlined here may be the most effective remedies. One of the most interesting approaches to this difficult problem lies in the creation of farm-level incentives for water-table control. For example, in the Punjab in Pakistan, 150,000 private tubewells installed in the past 15 years to supplement canal water deliveries have played an important role in controlling rising regional water tables.

CONCLUSIONS

Irrigation has been an extremely important factor in agricultural productivity growth in Asia; indeed, the food security of many nations critically depends on the productivity of their irrigated lands. Given the dependence on irrigation to feed the global population, the question is not whether to irrigate, but how irrigation planning and management can be done in a sustainable manner. To ensure a sustained contribution of irrigation to agricultural productivity growth, a long-range planning framework should be used that places more emphasis on cost-effective selection of projects to meet long-term agricultural production goals than on excessive response to short-term world price changes. At the same time, institutional reforms are needed within existing systems to improve the structure of incentives for both irrigation system managers and farmers to increase the efficiency and productivity of water use.

Public Policy and the Production and Distribution of Improved Seeds

CARL E. PRAY

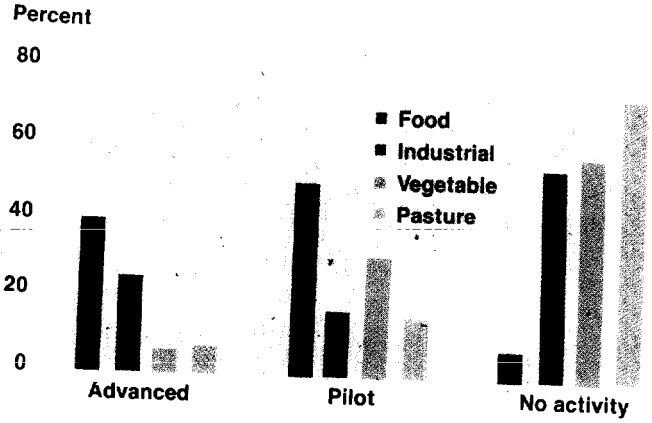
The seed industry is crucially important to agricultural development. Seed was the carrier of "green revolution" technology to farmers. As the new biotechnology moves from the laboratories to the fields of developing countries, seed will be even more important because it will be the primary method by which biotechnology reaches farmers. Policymakers must face four sets of issues related to the seed industry.

HOW CAN A COUNTRY BUILD A SEED INDUSTRY?

Almost all countries have some crops that are not well served by commercial or government seed supplies. The Food and Agriculture Organization of the United Nations (FAO) rated the level of development of seed production and distribution in 92 developing countries in 1985. Figure 1 indicates that food crops are most developed—40 percent of the countries had advanced industries, 50 percent had pilot or fragmentary activity, and only 10 percent had no activity. More than half the countries had no activity in industrial, vegetable, and pasture seed production and distribution.

In many countries the problem lies with the research system rather than the seed industry. If research has not developed varieties that produce higher yields or superior quality, seed produced by private or public corporations will not be able to compete with farmers' retained seed. There is no easy formula for judging the adequacy of the seed industry. Common measures such as low seed replacement rates (the ratio of seed purchased to total seed used) do not indicate whether the seed supply is inadequate for self-pollinated crops such as wheat and rice. In the Indian Punjab, farmers produce 3.26 tons per hectare of wheat but purchase only enough "certified/quality" seed to plant 1.2 percent of their wheat. In the mid-1970s in the United Sates, farmers purchased only 10 percent of their wheat seed and produced the rest themselves.

Figure 1
Levels of development of the seed industry in developing countries, by crop type, 1985



Varieties that produce higher yields or quality may be available, but they are not reaching farmers quickly. This is most often the case for hybrids that farmers can not easily reproduce. Then government officials must decide how to increase supplies to gain the greatest benefits to society given their budget and political constraints. Three principle strategies have emerged.

1. **The government produces and distributes commercial seed.**

Thirty-two of 37 countries surveyed recently by CIMMYT had public seed enterprises that supplied maize seed.

2. **Encourage small seed firms and farmers to grow and sell improved varieties through technical assistance on seed technology and quality control; subsidize equipment and the provision of foundation seed.**

The removal of price controls on seed and other restrictions may be important. This strategy has recently been used successfully in Bolivia and was used in India in the 1960s.

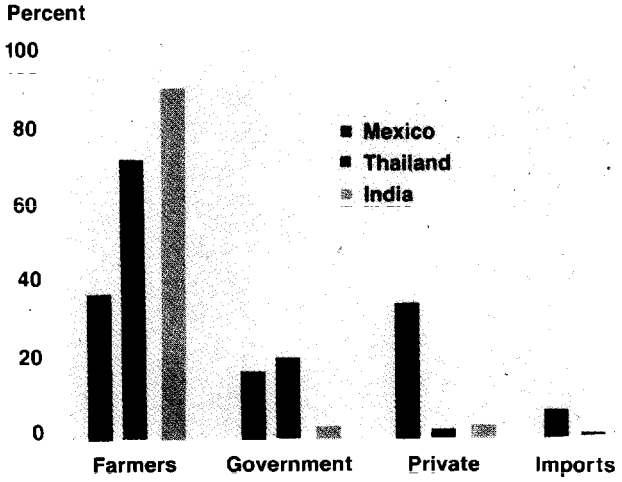
3. **Encourage larger companies, both locally owned and foreign, to enter the seed industry or expand into new crops.**

This strategy includes the same policies mentioned in strategy 2 plus public research and development on hybrids to support private R&D and stronger intellectual property rights. Chile and Argentina have been following this strategy quite successfully.

PRIVATIZATION

In many developing countries with relatively developed seed industries the public sector plays an important role in supplying seed. Figure 2 shows the contribution of government, farmers, private seed companies, and imports to total seed sown in Mexico, Thailand, and India. Privatization is an issue because many developing-country governments such as Mexico are trying to reduce their budget deficits, and public seed supply is an important drain on the government budget in some countries. In addition, the World Bank, U.S. Agency for International Development, and other donors are encouraging developing countries to privatize seed production, distribution, and in some cases plant breeding research.

Figure 2
Sources of seed in Mexico, India, and Thailand



Privatization is not an important issue unless government supply is a serious financial drain on the government or it prevents the development of competition through price controls or legislation that gives the government a monopoly. In countries as diverse as Zambia and India, government seed production is deep in the red. In East Africa, government-owned companies or regulated cooperatives have monopolies over the production of major field crops.

There are no studies as yet on the optimal amount of public supply of services in the seed industry, but some of the limits of privatization are known. Private companies will only conduct research on hybrid crops like corn, sorghum, and sunflowers—not on self-pollinated crops like wheat and rice—unless there are enforceable plant breeders' rights (ownership rights to plant varieties produced by an individual or company). Large private companies will not invest much in the production and distribution of most self-pollinated crops because the companies cannot compete with farmers. Large commercial companies will not invest in seed production for small markets of hybrids. Therefore multinational corporations (MNCs) will not invest in seed production and distribution in small-country markets.

At a minimum, developing-country governments must continue to breed self-pollinated crops and produce enough foundation seed to ensure that farmers can spread new varieties. Also, government research must supply sufficient breeders' seed and foundation seed so private companies can multiply and distribute new varieties to farmers.

DO RESTRICTIONS ON SEED IMPORTS REDUCE TECHNOLOGY TRANSFER?

Many countries wish to be self-sufficient in seed production and plant breeding research because seed is an essential ingredient in agriculture. This goal is reinforced by shortages of foreign exchange and concern that imports will transfer plant diseases. As a result developing countries restrict seed imports and investments in the seed industry by foreign companies. Developing countries are now being pressed by donors and some local interest groups to liberalize their policies on trade and foreign investment. The key question is how much output will farmers lose due to these restrictions on technology transfer?

The gains from liberalization of import policies will depend on how much technology is available from regions with similar agroclimatic conditions. Greece, Italy, and Chile have successfully imported and planted as much as half of their hybrid corn seed from the United States because their growing conditions are similar. Most developing nations in the tropics cannot benefit greatly from direct imports from temperate regions where most developed seed industries exist. As developing country seed industries mature there will be greater benefits from increasing trade with other countries in the tropics.

The transfer of varieties for use in breeding programs has been more important than seed imports as a means of technology transfer. In wheat and rice, government research in developing countries has been able to make use of varieties from Mexico, the Philippines, and elsewhere as parents for breeding successful high-yielding varieties. In maize, governments and MNCs have adapted improved lines to the tropics by breeding them with locally developed varieties. Recent studies show that the more MNC research there is in a tropical country, the higher the maize yields, which indicates the positive impact that MNCs can have.

Therefore, while trade offers limited opportunities for growth, public and private sector research to adapt exotic varieties does have large payoffs. Governments should be encouraging such research.

BREEDERS' RIGHTS, FARMERS' RIGHTS, AND GENETIC DIVERSITY

Plant breeders rights are being promoted in developing countries by private seed firms, the U.S. government, and some European governments as a means of encouraging more private research and technology transfer. The opponents of such legislation view it as a way in which private companies—particularly European and U.S. multinational companies—can extract money and genetic resources from farmers in developing countries. The opponents of breeders' rights have proposed strengthening "farmers' rights" instead. They propose that developed countries compensate developing-country farmers for past use of their genetic resources by financing research on and conservation of genetic resources in developing countries.

This debate has been extremely useful in emphasizing the importance of preserving germplasm. There is general agreement that more money needs to be invested in identifying, describing, and preserving germplasm. A number of countries are making major investments in germplasm preservation. The discussion on farmers rights may encourage more investment in germplasm preservation by developed-country governments and the companies based in them.

However, the rhetoric about plant breeders' rights seems to have been blown out of proportion. The only developing countries that have plant breeders' rights laws that they are actively enforcing are Argentina and Chile. India is discussing plant breeders' rights, but it appears that in India and other developing countries they would be very difficult to enforce. This has often been true even in the United States; therefore they have had a limited effect on research or crop productivity.

Fertilizer Policy Issues and Sustainable Agricultural Growth in Developing Countries

GUNVANT M. DESAI

Until recently, growth of fertilizer use was universally acknowledged as crucial to raising agricultural production in the developing world. But with growing awareness of environmental degradation, doubts are sometimes cast on this position. One also hears about increased emphasis on organic manures and other alternatives such as organic farming, biological nitrogen fixation (BNF) technology, and alley cropping.

The real question concerning fertilizers in developing countries is not *whether,* but *how* to step up growth in fertilizer use with minimum adverse effects on the environment. Discussions that ignore this distinction often distract policymakers' attention from the many complexities and dilemmas inherent in attempting to raise agricultural production continuously.

GROWTH IN FERTILIZER CONSUMPTION

Since the early 1960s, the developing world has raised its annual fertilizer use from about 5 million metric tons to more than 50 million metric tons. This growth looks impressive when compared with the 33 million tons used by developed countries in the early 1960s—some 12 decades after use of chemical fertilizers began in the 1840s. The long-term trends of fertilizer use in most developing countries outside Sub-Saharan Africa have been robust and resilient, despite oil crises, growing debt burdens, and an unfavorable world market environment.

But fertilizer use per unit of cultivated land in many developing countries, and at some locations in all of them, is still quite low (Table 1). Several studies indicate that total fertilizer consumption in developing countries needs to grow from 57 million tons in 1987/88 to more than 100 million tons by the year 2000 to raise food and agricultural production to desirable levels.

ENVIRONMENTAL CONCERNS AND FERTILIZER

There are basic reasons why environmental concerns should not indiscriminately obstruct further growth of fertilizer use in the developing world, where environmental degradation is largely due to the widespread incidence of poverty, and where the typical interplay of key factors such as arable land, income, population, health, and education is affected by the low levels of economic development. The rapid growth of fertilizer use in many developing countries has played a key role in their escape from the Malthusian trap characterized by growing human misery and environmental degradation. Also, it has initiated technological transformation of traditional agriculture, which is not altogether environmentally benign.

When discussing fertilizer policy issues, one must distinguish between the developed and the developing countries, and not just because their levels of fertilizer use are different. In the developed world, the pertinent question is whether the present high rates of fertilizer use are "excessive" to maintain high yields per unit of land. In the developing world, sustainability issues need to be viewed in the dynamic context of continuous growth in yields required to maintain growth in agricultural production. Clearly, the objectives of fertilizer policy cannot be the same in the two worlds.

At present, cost-effective alternatives to chemical fertilizers for continually raising crop yields—alternatives that are practicable on millions of hectares of hungry soils in the developing world—are not available. Surely, organic manures, BNF technology, and other alternatives must play a complementary role to chemical fertilizers. But given the historical experiences of the developed world and present day realities in developing countries it is naive to view them as substitutes for fertilizers where growing requirements for plant nutrients must be met.

Similarly, it may be valid to say that fertilizer use is "excessive" in certain developed countries and that this could be corrected through price policy instruments, but in developing countries, pockets of excessive fertilizer use are few. And even in those pockets, adverse environmental effects are commonly due to deficiencies of micronutrients or trace elements in soils and flawed fertilizer practices, such as imbalance among nutrients and unscientific methods and timing of application. An effective solution for these problems lies not so much in price policy reforms as in enlarged, location-specific research and extension efforts, as well as improvements in the capabilities of fertilizer supply and distribution systems.

To argue against growth of fertilizer use in developing countries by pointing to its direct adverse environmental impacts in selected developed countries is both hasty and short-sighted. In fact, some of the above considerations suggest that the positive contributions of chemical fertilizer in arresting environmental degradation could be greater than its direct negative effects. Fertilizer could also be an important tool in combating soil erosion and deforestation—the two dominant elements in environmental degradation.

Table 1
Distribution of countries according to fertilizer consumption per hectare of arable permanent cropland, 1972 and 1987

Economic Classes and Regions/Year	Fertilizer Consumption (kilograms/hectare)									
	Less than 10	10-19.9	20-29.9	30-39.9	40-49.9	50-74.9	75-99.9	100 or more	Total	Average Consumption
	(number of countries)									(kilograms/hectare)
Developed countries										
1972	0	0	0	2	0	5	5	22	34	92
1987	0	0	1	0	2	1	2	28	34	124
Developing countries										
1972	49	10	11	7	5	6	5	17	109	23
1987	37	6	7	7	4	15	9	24	109	71
Market economies										
Africa										
1972	32	4	1	2	0	1	0	2	42	6
1987	29	4	2	3	1	1	0	2	42	12
Latin America										
1972	4	2	5	4	2	2	5	9	33	25
1987	4	0	2	1	2	8	6	10	33	51
Near East										
1972	8	1	1	0	1	0	0	3	14	18
1987	2	0	1	2	1	3	0	5	14	57
Far East										
1972	3	2	4	0	0	2	0	2	13	20
1987	1	1	2	0	0	2	2	5	13	63
Others										
1972	0	1	0	0	1	0	0	0	2	13
1987	0	0	0	1	0	0	1	0	2	31
Centrally planned economies										
Asia										
1972	2	0	0	0	1	1	0	1	5	52
1987	1	1	0	0	0	1	0	2	5	219

Source: FAO.

A FRAMEWORK FOR UNDERSTANDING CONSTRAINTS AND POLICY REQUIREMENTS

Fertilizer policies can best be discussed within a framework that views growth of fertilizer use as an outcome of the interplay of all essential elements under typical circumstances in developing countries.

The agronomic potential of fertilizer use in a country is determined by factors such as soil quality, climatic environment, cropping pattern, genetic characteristics of crops, and use of inputs other than fertilizers. The economic potential of fertilizer use is determined by these factors and prices of crops and inputs, including fertilizers. Actual fertilizer use is an outcome of the conversion of the economic potential into farmers' effective demand for fertilizers and the fulfillment of this demand through fertilizer supply and distribution systems.

Forces behind growth in fertilizer use may be viewed as development of and interactions among four sets of processes: (1) those that influence the agronomic potential of fertilizer use through development of resources such as irrigation and new technology that shift fertilizer response functions upward; (2) those that convert the potential into farmers' effective demand for fertilizers by providing them with knowledge on fertilizer use, credit, and assured markets for output; (3) those that determine the growth of aggregate fertilizer supply through imports and domestic production; and (4) those that help develop geographically dispersed fertilizer distribution systems and determine how they operate.

Three major elements in the operating environment that influence these processes and interactions are prices, institutional set-up, and macroeconomic conditions. National objectives and government policies affect growth in fertilizer use through their direct and indirect influence on the four processes and the major elements of the operating environment.

This framework suggests that the factors governing growth of fertilizer use are varied and interrelated. Also, their relative importance in constraining growth would differ at different locations and times. This is especially so in the developing world where actual fertilizer use is typically less than the economic potential, and where the different processes behind growth of fertilizer use are neither fully developed nor equally governed by market mechanisms. Thus one cannot have a uniform policy prescription for all developing countries. Nor would the same prescription be equally valid in a country at all times.

CONCLUSIONS BASED ON PAST GROWTH

Empirical research on the growth of fertilizer use in developing countries, when interpreted in the framework

above, leads to six broad conclusions. These are useful in critically understanding past growth and also in reflecting on policies for future growth.

1. Of the four sets of processes behind the past growth of fertilizer use in developing countries, those that have raised fertilizer potential and enlarged fertilizer supply have dominated. Diffusion of fertilizer-responsive crop varieties and growth of irrigation have been the main forces behind the rising fertilizer potential. Enlarged fertilizer supply has come mainly through expansion of the domestic industry in many countries in the wake of the oil crisis. In addition to raising the social and private returns to fertilizer use and creating sustained growth in fertilizer supply from a domestic source, these processes have induced expansion of the agricultural extension, credit, and fertilizer distribution systems. This, in turn, has also accelerated the trends of fertilizer use on traditional varieties. The cross-country variations in growth of fertilizer use can largely be traced to the interplay of all these factors. In countries where fertilizer potential has not risen rapidly (many Sub-Saharan countries, for instance), supply-side constraints seem to have decisively influenced the pace and pattern of growth in fertilizer use.

2. Growth of fertilizer use would have been faster in virtually all developing countries but for major weaknesses in each of the four sets of processes: (1) lack of breakthroughs in crop varieties suited to diverse agroclimatic conditions, inadequate investment in irrigation and rural electrification, and lack of cost consciousness and efficiency in these activities; (2) inadequate geographical and crop coverage plus absence of location-specific research in extension efforts, weaknesses in agricultural credit systems, and constraints in markets for output; (3) poor planning and management of growth in fertilizer supply through domestic production and imports; and (4) inadequate geographical expansion, infrastructure problems, and inefficiencies in the fertilizer distribution system.

3. Government involvement on the fertilizer supply side has been pervasive because of virtual absence of the private sector in the initial stage, chronic foreign exchange constraints for fertilizer imports, an oligopolistic world fertilizer market, circumstances that led to public investment in expansion of the domestic fertilizer industry and the need to control allocation of supply to achieve specific goals.

4. On the demand side, apart from developing extension and credit systems, most governments have intervened by controlling the prices of fertilizers, with the objective of keeping them low and stable at the farmgate. Until the dramatic rise in fertilizer prices on the world market in the early 1970s, large fertilizer subsidies were uncommon. Since then the volume of fertilizer subsidies has increased substantially in most countries. However, in many countries, budgetary statistics do not reflect the true volume of fertilizer subsidies or the burden on fiscal resources because of the overall administered price environment and the importance of foreign aid in imports. Also, despite subsidies, the ratios of fertilizer to crop prices in many developing countries have been higher than in the developed countries.

5. In virtually all countries, geographical pockets of concentration in fertilizer use have emerged. These are areas with superior response functions and with better development of the processes behind growth of fertilizer use. Continued dependence on these areas for increased agricultural output has often generated pressures for more favorable prices due to diminishing marginal productivity of fertilizer. Policies have usually responded to these pressures to achieve short-term production targets rather than improving efficiency of fertilizer use in these regions and opening up new markets with untapped fertilizer potential through infrastructure development.

6. In Sub-Saharan Africa, countries with relatively better performance in raising fertilizer use are also the ones where food crops have a high share in total use. But in many countries, the bulk of fertilizer use has remained confined to a few export crops, which dominate foreign exchange earnings and government revenue, and growth has been poor and unstable. Unlike in Asia, growth of fertilizer use on food crops in Sub-Saharan Africa has been constrained by lack of major breakthroughs in crop varieties. But there appears to be considerable untapped potential for fertilizer use on food crops, especially maize. Therefore, poor diffusion of fertilizer use on food crops is very likely due to numerous deficiencies in the support systems, especially for the smallholder sector. Firm government commitment to develop both demand- and supply-side processes seems critical for removing these deficiencies. In this task, sustained growth in fertilizer supply is an essential precondition in the short run and raising fertilizer potential through technological breakthroughs is essential in the long run.

REFLECTIONS ON FUTURE POLICY REQUIREMENTS

Further growth of fertilizer use in the developing world must be increasingly seen as a means of increasing agricultural production in ways that alleviate poverty through employment-oriented economic development. The most essential feature of such growth is maximum technical and economic efficiency in fertilizer use. This depends on three actions: (1) vigorously promoting fertilizer use in regions and crops with untapped viable potential, (2) increasing efficiency of use in regions where per hectare levels have reached high levels, and (3) continually developing technologies that raise the productivity of fertilizer in crop production.

In developing policies for such growth, a fragmentary view of issues and confusion of short-term expediencies with long-term objectives need to be avoided. Similarly, government involvement in growth of fertilizer should not be considered either "inevitable" or "undesirable." Policy reforms in this matter should be guided more by practical considerations than by ideological preferences for or faith in the market forces and the private sector.

Given the critical importance of the supply side, the genuine constraints on rapid growth of fertilizer supply, and the historical developments behind government involvement in production and imports of fertilizer, it would be imprudent to rapidly disband the existing institutional arrangements. Reforms aimed at involving the private sector in fertilizer distribution, if they are not to be short-lived, must be accompanied by sustained efforts to accelerate growth of aggregate fertilizer supply and to remove physical infrastructure deficiencies.

Price and subsidy policy reforms are neither cost-free nor one-shot affairs. Also, the scope of reducing the burden of fertilizer subsidies on fiscal resources is often smaller than commonly believed. Yet these reforms seem overdue in many developing countries because subsidies cannot substitute for location-specific research to improve efficiency of fertilizer use; widespread diffusion of this knowledge among farmers; and vigorous development of agricultural credit, fertilizer distribution, and output marketing systems. The resources required to undertake all this would most likely exceed the savings from the elimination of subsidies in the short run, but the long-term benefits would be substantial. Persistent deficiencies in the support systems are a liability, not only for efficient growth of fertilizer use but also for technology-based agricultural growth that alleviates poverty through employment-oriented economic development.

Agricultural Credit Policy For Technological Change

BHUPAT M. DESAI AND JOHN W. MELLOR

Agricultural credit policy aims to facilitate rural growth with equity, integrate rural financial markets, and enlarge the economies of scale and scope for viability of formal rural financial institutions (RFIs), that is, public and private lending institutions such as commercial banks. Two main instruments for achieving these goals are promoting appropriate RFIs and maintaining moderately low interest rates. These policies to develop RFIs work best in the context of new technology that reduces the cost of production per unit of output.

Modern forms of capital and an efficient capital market influence not only prices but also growth and employment. Rural capital market development is a complex process. This is because agriculture is small scale, geographically widely dispersed, weather dependent, lacks commercialization, and is deprived of basic infrastructure and education. It is also because the rural loan demand is more elastic to the real interest rate than rural savings in general and rural financial deposits in particular. But, rural households' borrowing, saving, and deposit responses to the availability of accessible and appropriate RFIs are elastic. Thus, a widespread system of rural branches is important. In these circumstances, developing a public-sector role for rural credit is inevitable, though a widespread system of RFIs may be expected to absorb start-up losses. The issues are how to develop that role, for what purposes, and with what policies.

A developing rural credit system may be subject to political abuse, because of its dispersed character, the nature of rural politics, and inappropriate interest rate policies. As a consequence, loan quality may be poor and loan delinquency widespread. However, other reasons for the viability problem of rural credit institutions are far more important. They relate more directly to inappropriate features of the policy of promoting formal institutions than to interest rates. This brief outlines a more appropriate strategy for development of RFIs that stresses developing multiple financial agencies that are functionally and vertically integrated, with high coverage of farmers and geographic areas.

PROMOTING APPROPRIATE FORMAL INSTITUTIONS

Nationally integrated RFIs are necessary and desirable for accomplishing financial intermediation between surplus and deficit seasons, years, regions, and economic subsystems. The need to develop RFIs is shown by historical patterns in the relative role of formal and noninstitutional lenders. In the process of economic development, formal lenders have played an increasingly large role relative to informal lenders. Among the reasons for this increasing role are problems resulting from differences in the outward shift in demand and supply schedules for capital induced by widely dispersed agriculture with uneven availability of new technology; problems arising from weather instability and low and static incomes of farmers; financial requirements for land reform and redemption of old debt during calamities; and the weaknesses of informal lenders. There has been a strong secular increase in the relative role of institutional credit and a consequent decline in noninstitutional credit in Asian high-income, middle-income, and low-income countries. Cross-national data on various countries in six different geographical regions suggest a similar conclusion.

Given the need for RFIs, how should their development be structured? First, although there is little or no empirical evidence, logic and observation favor a multiagency approach, which provides a choice to farmers. Because RFIs have major problems with economy of scale, a large number of competing agencies may be undesirable. However, unlike a single-agency approach, a multiagency approach has the potential to generate competition. Other reasons for a multiagency approach are shifts in the term structure of demand and supply schedules for financial services; the lack of comparative advantage of the existing RFIs due to their ill-suited term structure of financial resources and their inability to serve the rural poor, especially in more difficult agricultural areas; and increasing availability of trained manpower over time. Historical experiences of countries around the world show that the multiagency approach is common in both developed and developing countries. The average absolute number of types of RFIs is higher in high- and middle-income countries than in low-income countries.

What should be the form of organization of rural financial institutions, that is, should they be government or autonomous public agencies or private agencies or cooperatives? Again, historical experience shows that all these forms are found world over. But the process of promoting RFIs typically begins with government departments or cooperatives, because commercial banks are reluctant to enter the rural financial market—perhaps largely due to initial problems of scale and the difficulty of supervising widely

dispersed small branches. Government programs are ubiquitous even in the later stage of development in Japan, the United States, Taiwan, and South Korea. But they are well-integrated with the rest of the formal RFIs.

The second important organizing principle for RFIs is vertical integration. Vertically organized RFIs are needed because they are capable of integrating national and regional financial markets, providing human know-how to their lower-level units, and decentralizing decisions on rural financial operations. Such capability is weak in Africa, the Near East and Mediterranean Basin, and South America, compared with Asia.

Improving the density of RFIs is also extremely important to the development of the rural financial market. Although scale economies may be adversely affected, increasing density is still important because it improves accessibility for both rural households and the formal lenders and lowers farmer's transaction costs of borrowing. Increased density also enables intensification and widening of the scope of operations to develop scale economies, which are crucial for spreading lenders' common transaction costs. Moreover, it facilitates effective competition with informal lenders. Both the density of RFIs and coverage of farmers are lowest in Africa, followed by the Near East and Mediterranean Basin, South America, and lastly Asia. Density (the number of field-level RFIs to 1,000 hectares of arable land) is highest in Japan (4.6), followed by China (3.7), Taiwan (1.3), South Korea (1.1), India (0.7), two Southeast Asian middle-income countries (MICs) (0.39), and four South Asian lower-income countries (LICs) (0.3).

It is also advantageous for RFIs to be multifunctional. Multifunctional RFIs directly and indirectly undertake operations of farm-level loans (both in cash and kind and in short and longer terms), extension, input sales, produce marketing, consumer goods sales, deposits and/or capital collection, other borrowings, and loan recovery.

Multifunctional RFIs are advantageous for three reasons. First, farmer-level credit acts as an impetus to investment in real resources, which must be matched by supplies, which in turn could be encouraged by loans to input and produce marketing agencies. Through these types of agricultural credit, RFIs can forge much needed backward and forward linkages among agricultural production, agricultural input distribution, and agromarketing and processing subsystems. These linkages improve the efficiency of agricultural productivity and the economies of scale and scope, and thereby increase viability.

Second, multifunctional RFIs also accelerate the consumption linkages of technological change because they have a larger impact on rural incomes, as a result of the stronger and noninflationary production and saving linkages mentioned above.

Third, RFIs are an effective alternative to informal lenders who undertake a range of functions. In most developing countries, informal private lenders' operations are characterized by horizontal integration of local commodity, land, labor, and credit markets. Both horizontally and vertically organized RFIs are widely found in developed countries, such as Japan, the United States, South Korea, and Taiwan, and to a lesser extent in developing countries such as Bangladesh, India, Malaysia, and Thailand.

Transaction costs as a percentage of all assets plus liabilities of RFIs are lower where their density, coverage, and multifunctional roles are better; they are 1.1 percent in Taiwan, 1.5 percent in South Korea, 1.7 percent in the Near East and Mediterranean Basin MICs, 2.00 percent in Asian MICs, 2.4 percent in Asian LICs, 2.8 percent in South American MICs, and 3.1 percent in African MICs.

A successful example of a diversified agency is the Grameen Bank in Bangladesh, which not only makes farm-level loans, but also lends to local agroprocessing businesses and shops. It also collects deposits, recovers loans, and borrows from other agencies. This bank has encouraged investment, employment, and occupational diversification, in addition to increasing incomes and lowering poverty among the rural poor. It has also achieved viability, high rates of loan recovery, scale economies in financial costs, and constant returns to scale in transaction costs. Its rural branches achieved scale economies in transaction costs within three years of their inception. Moreover, this bank has been an effective alternative to noninstitutional lenders whose operations are similar to those described earlier.

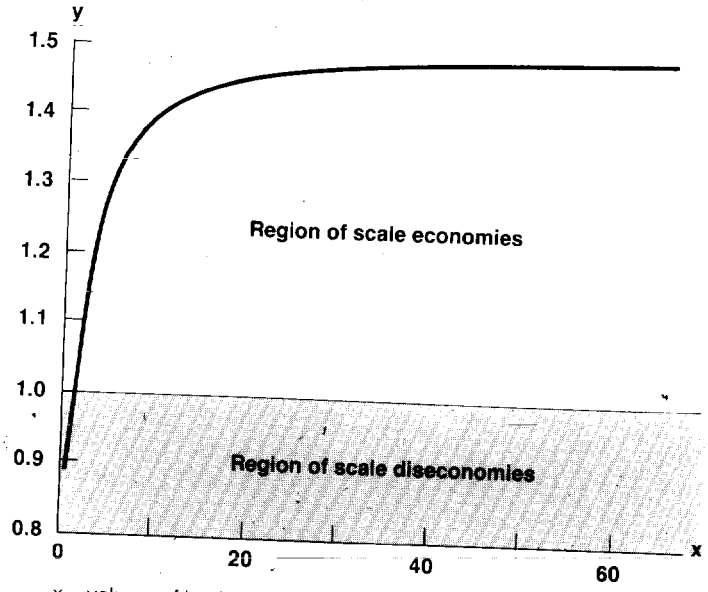
Regional Rural Banks (RRBs) in India have also to some extent diversified their operations in a manner similar to the Grameen Bank. In the late 1970s they lowered their unit transaction costs and improved profitability. Farmers under the purview of a multifunctional village cooperative in India have larger investments, more optimal allocation of resources, better technology, and higher productivity and incomes than those served by less diversified village cooperatives in the same agroclimatically backward area. A sample of mostly rural branches of the nationalized commercial banks in India reveals that they enjoyed scale economies in transaction costs in the mid-1980s. These branches, however, suffered from scale diseconomies in costs when their operations were only about Rs 1 million, but they rapidly reaped scale economies once operations grew to about Rs 30 million. These economies moreover continued even beyond a volume of business of Rs 60 million (see Figure 1).

Furthermore, the adoption rates for high-yielding varieties and agricultural productivity were higher and the loan delinquency rates were lower in states of India where the density of RFIs was higher. In these states loans to farmers and those to input distribution agencies were also higher and more diversified. Village cooperatives in these states were multifunctional and achieved scale economies in their transaction costs.

In India, fertilizer use, irrigation, other agricultural investments, and agricultural productivity have increased over time, with the increase not only in the density of RFIs and farm-level credit, but also in loans for distribution of agricultural inputs, cooperative marketing of produce, and to processing agencies. Nevertheless, at the all-India level, loan delinquency is high and scale economies in transaction costs have not been fully achieved. Had the institutions sustained increases in their density, coverage of farmers, scale and scope of farm-level loans, and multiproduct operations more continuously, institutional credit would have had a much larger effect on agricultural investments and productivity, and on profitability and loan recoveries.

More sustained and disciplined integrated institutional credit of the type described above can further lower already declining interest rates of informal lenders. This rate has decreased by 25 percent over two decades from 1948-51 in 13 developing countries spread over Africa

Figure 1
Behavior of scale economies in transaction costs of sample rural branches of nationalized commercial banks in India, mid-1980s



x = volume of business (Rs million).

y = reciprocal of the elasticity of transaction costs with respect to volume of business.

Source: Bhupat M. Desai and John W. Mellor, IFPRI.

(Nigeria), Asia (India, Indonesia, Pakistan, the Philippines, South Vietnam, Sri Lanka, and Thailand), South America (Colombia, Honduras, and Mexico), and the Middle East (Jordan and Lebanon).

MAINTAINING MODERATELY LOW INTEREST RATES

Interest rate policy is perhaps even more complex than promotion of formal RFIs. Most transaction costs of an RFI are shared jointly by its various activities, including credit. The spread between borrowing and lending rates for agriculture is not the only source of revenue for RFIs. Other sources include the interest spread for other subsystems of agricultural development, commissions on nonfund-based credit, discounts on bills, check-clearing fees, and income from nonfinancial activities. Moreover, policy aims to evolve viable intermediaries rather than one single activity like credit or deposit.

Recognizing this, it is a better analytical approach to understanding many common transaction costs and the unit net margin of an RFI rather than those of its single activity. Furthermore, raising borrowing rates in isolation from lending rates acts as a disincentive to RFIs without promoting significant growth in rural deposits. Similarly, raising lending rates in isolation from deposit rates acts as a disincentive to rural borrowers, which is eventually counterproductive to the basic goals of a rural financial system.

The rationale for maintaining moderately low interest rates is straightforward. On a macroeconomic level, raising lending or deposit rates can lead to cost-push inflation, lower growth and saving rates, and bankruptcy, as was found in recent financial reforms in South Korea, Brazil, Chile, and Turkey. At the sectoral level, loan demand decreases more than proportionately in response to increases in the lending rate in developing countries, unlike developed countries. Moreover, the interest rate has a greater impact on rural loan demand than on the supply of rural savings, and rural deposits in developing compared with developed countries. Therefore, raising interest rates excessively in the developing phase will tend to choke off rural loan demand without inducing substantial new financial deposits. In addition to the direct negative effect on economic activity, the adverse effect on growth in rural loans will retard development of scale economies in the operations of the RFIs.

A feeble response of rural deposits to interest rates is in significant part due to farmers preferences for holding their savings/assets in physically productive resources rather than in financial deposits. Further, the interest rate is less important a determinant of both rural loan demand and rural deposit supply than nonprice factors in developing, as well as developed, countries. In developing countries, these factors mainly include the existence of new technology, the density of formal RFIs, and their multiproduct operations. In addition to the last two factors, the safety and liquidity of these institutions' deposit facilities largely determine the supply of rural deposits in these countries.

Whether total rural saving (physical plus financial) will increase or decrease with the increase in the real interest rate cannot be stated a priori because of its positive substitution and possibly negative income effects. Empirical evidence on farm-households in Indian districts, Taiwan, and South Korea shows that this response is positive but inelastic. This result is due to a very high positive substitution effect of the rate of return, which has more than offset the possible negative income effect or been reinforced by this impact also being positive. Such a result may have been induced by rapid and widespread technological change in agriculture. Moreover, rural saving is also influenced more by factors other than the rate of return. Most of these noninterest factors center around some measure of the ability to save.

CONCLUSIONS

For developing countries, three implications can be drawn. First, promotion of a nationally integrated formal rural financial market with sustained government support is absolutely essential to transfer of new technology for agricultural development. Second, in so doing, improvements in vertical organization, density, coverage of farmers, and the functional structure of formal RFIs are central to their clients' well-being and to their own. And third, these improvements, together with maintaining moderately low interest rates, are far more important to achieving the objectives than presently recommended financial liberalization.

Fertilizer and Output Pricing Policies for Sustainable Growth

MARK W. ROSEGRANT AND RAISUDDIN AHMED

Governments have historically intervened actively in agricultural input and output markets in most developing countries. Governments subsidize or tax the prices of key inputs such as fertilizer and water, manage foreign exchange markets, control imports and exports of commodities, procure and distribute food and feedgrains, attempt to maintain floor and ceiling prices in markets, and regulate private trade. Price policies critically affect the structure of incentives for agricultural production. This brief examines the criteria for the setting of fertilizer and agricultural output price levels.

FERTILIZER PRICE POLICY

Governments have intervened in the setting of fertilizer prices in support of a number of broad-based policy goals. Many countries have protected domestic fertilizer production by restricting imports or maintaining import tariffs. In the Philippines, for example, domestic fertilizer prices were maintained well above world prices through the mid-1980s by a combination of import controls and subsidies to domestic fertilizer plants.

Subsidies for the domestic fertilizer industry have arisen from a number of historical reasons, including infant industry protection; protection for the agricultural sector from uncertainties in fertilizer supply and prices in the world market, such as occurred most dramatically during the oil crises in the early 1970s; and support for the fertilizer industry as a component within integrated domestic production processes.

More commonly, governments have subsidized farm-level fertilizer prices in support of several objectives, including income support for farmers and provision of incentives to increase the rate of adoption and level of fertilizer use, to increase crop production, and to balance other taxes against agriculture. In Indonesia, subsidies have been maintained both for farmers and for the domestic fertilizer industry. The total fiscal costs for the two types of fertilizer subsidy were about Rupiah 670 billion (US$407 million) in 1986, representing nearly one-half of total government development expenditures for agriculture and irrigation. Fertilizer subsidies in Bangladesh in 1983/84 accounted for about 14 percent of its budget allocation to agriculture.

FERTILIZER PRICING CRITERIA

Governments have thus used a number of criteria for pricing of fertilizer in pursuit of diverse objectives. In order to evaluate the social costs and benefits of different pricing policies, it is necessary to define a reference social price, which represents the marginal cost to the society of obtaining the marginal unit of fertilizer. If the primary concern of fertilizer pricing policy is productivity growth and hence efficiency in production, the world price is the appropriate reference point for domestic price determination, because it represents the cost to the society of purchasing fertilizer.

If a country is a net importer of fertilizer, the social price is the world or import price of fertilizer plus domestic marketing and distribution costs. If the country is a net exporter of fertilizer, the social price of fertilizer is the cost of efficient domestic production and distribution.

In the absence of externalities, if free import of fertilizer is permitted and if fertilizer is distributed to farmers through an undistorted marketing and delivery system, private (or farmer) prices and social prices of fertilizer are equal. However, as noted above, many governments have introduced differences between social and private prices through fertilizer subsidies, import tariffs, or nontariff barriers to trade.

In general, input subsidies and taxes that cause differences between private and social costs distort production incentives, creating inefficiency and reducing productivity growth. Taxes on fertilizers, in the form of tariffs or other import restrictions, subsidize inefficient domestic producers of fertilizer and reduce fertilizer use and food and agricultural production to less than socially optimal levels.

Fertilizer subsidies to farmers, on the other hand, can become extremely costly to government treasuries, soaking up funds that could be used for alternative investments, and they can induce the overuse of fertilizers relative to socially optimal levels. To the extent that subsidies are not fully funded to provide enough fertilizer to meet demand at the subsidized price, excess demand will be created, which can contribute to nonprice rationing, nonavailability of fertilizer, black markets, poor logistics, and untimely delivery of fertilizer.

Given these potentially significant negative effects of subsidies, are there appropriate uses for fertilizer subsidies to farmers or industry? Fertilizer subsidies to farmers may be cost-effective in stimulating farmers to adopt and appropriately utilize fertilizer together with new production technology. Temporary subsidies during the early stage of adoption of fertilizer may be effective in overcoming the fixed costs related to adoption of new technology and in inducing farmer experimentation and learning during periods of rapidly changing technological potential.

A similar argument could be made to provide direct subsidies to the domestic fertilizer industry during the early stages of establishment of the industry. Such support can only be justified when combined with policies to induce the industry to become efficient within a reasonable time frame. Subsidies to induce rapid adoption of new technology or to protect an infant industry should necessarily be temporary, and should be phased out as adoption and appropriate use of fertilizer become widespread. Otherwise, with increasing production and use of fertilizer, the budgetary cost of the subsidy becomes prohibitive, production incentives are distorted, and resources are misallocated as described above.

In reality, it has proven difficult to phase out fertilizer subsidies once they are in place, because of the strong political support that develops as the subsidy becomes institutionalized. However, Indonesia, which has used fertilizer subsidies as one of the key policy instruments in promoting the spread and intensification of use of fertilizer, is now in the process of gradually phasing out fertilizer subsidies.

FERTILIZER PRICING AND ENVIRONMENTAL EXTERNALITIES

In addition to government policies, a second major source of differences between private and social benefits and costs are external economies or diseconomies arising from the production process. External economies occur when producers confer benefits on other members of society, but are unable to obtain payment for those benefits. External diseconomies occur when farmers as producers impose costs on other members of society without paying fully for these costs. Under these circumstances, the pursuit of private gain does not promote social welfare.

A good example of an external diseconomy occurs with heavy use of chemical fertilizer. Heavy use of chemical fertilizer may cause long-term adverse effects on soil structure and crop productivity and excessive drainage runoff, which imparts negative externalities to other farmers and consumers through pollution of groundwater, rivers, and lakes. Conversely, there is an external economy to using organic fertilizers such as green manure because of their long-term positive impact on soil structure and productivity and provision of micronutrients, some of which are not available from chemical fertilizers. (This can also be interpreted as an additional diseconomy of chemical fertilizer use.).

This external economy is not a pure externality, because part of the benefits of organic fertilizer use (or costs of chemical fertilizer use) accrue to the farmer. However, because of the long-term nature of those benefits, the use of chemical fertilizer instead of organic fertilizer represents a partial trade-off of future benefits for present gain. Because private discount rates are generally higher than social discount rates, this trade-off will generally not be reflected in the farmer cost of chemical fertilizer.

The key price policy question is whether the environmental externalities of chemical fertilizers in developing countries are serious enough so that taxes on chemical fertilizers should be used to encourage a shift from chemical to organic fertilizers. Although additional research is needed on many aspects of this question, available evidence indicates that such a tax is not advisable.

First, there is little evidence of substantial, widespread negative externalities from chemical fertilizer use in developing countries. Second, the economic feasibility of the current technology for green manures and alternative organic fertilizers is generally poor due to high opportunity costs of labor and/or land in the production and application of these fertilizers. Third, the supply of organic fertilizers appears to be highly inelastic.

Because the difference between private profitability of chemical and organic fertilizers is so great, a large tax on chemical fertilizers would be required to induce significant switches from chemical to organic fertilizers. Such a tax is not justified based on available evidence on externalities from chemical fertilizers. Instead, it would be more appropriate to continue funding of research programs designed both to overcome the constraints to economic feasibility of organic fertilizers and to improve the technical efficiency of chemical fertilizer use and minimize its adverse environmental impact.

OUTPUT PRICING CRITERIA

Most countries with predominantly market economies have taken a pragmatic approach to pricing of agricultural output, employing a mixture of pricing based on the costs of production, parity pricing relative to other domestic prices, and use of world prices as guides for the fixing of producer prices. However, if the primary concern of agricultural pricing policy is productivity growth and hence efficiency in production, the world price is the appropriate reference point for domestic price determination, just as in the case of input pricing policy The domestic equivalent of the world price is computed at the appropriate exchange rate and adjusted for domestic transportation and marketing costs.

Departures from the world price necessarily entail costs to the economy. If the domestic price of a commodity is lower than the world price, farmers are being penalized and incentives to production reduced. Raising the price to the world level will induce increased production and reduce imports or increase exports of the commodity. If the domestic price is higher than the world price, consumers are being penalized, and excess productive resources are devoted to production of the commodity. The country can therefore gain by allowing imports, which will reduce the domestic price, improve consumer welfare, and release productive resources to other crops with a comparative advantage in production.

Adoption of the world price as a base for domestic pricing policy does not imply commitment to a free-trade policy. Governments use price policies to pursue many goals, some of which are conflicting, such as income

support for farmers and maintenance of low food prices for consumers. However, the world price reference point provides a means for assessing the social costs of pursuing other goals through a domestic pricing policy that causes a divergence between domestic and world prices.

For example, if the overriding objective of the country is self-sufficiency in a commodity, then the appropriate domestic price is the one that will balance supply and demand in the domestic market. Formulation and implementation of domestic price policy in such a situation may completely ignore world prices. Assessment of the effects of the self-sufficiency policy, however, should utilize the world price in estimating the marginal social benefits and costs of the policy.

Cost of production is a widely used alternative pricing criterion in both developed and developing countries. Generally, the average cost of producing a unit of output, rather than the marginal cost, is used as a reference point in fixing producer prices. There are several other problems in using cost of production as a guide. First, the cost of specialized resources (such as land) is demand-determined and therefore is affected by product price. Accommodation of this cost in the fixing of price involves circularity. Every time the product price is raised, the cost of these resources will also rise and the administered price will have to be raised. Second, because of uncertainty, the cost that determines producer decisions is a subjective opportunity cost that cannot be measured objectively. Third, since differences in costs among farmers and regions is very high, the choice of groups and regions whose cost is to be fully covered by the administered price will be arbitrary. An arbitrary choice of a cost estimate may generate enormous problems of interregional or intergroup income distribution. Moreover, the production conditions in agriculture, as dictated by factor and product market imperfections, make the cost estimates deviate more widely from their true opportunity costs than would be expected in industrial production. Thus, fixing prices on the basis of cost of production is even less likely to approach optimality in agriculture than in industry.

IMPLEMENTATION OF OUTPUT PRICING POLICY

Implementation of an output pricing policy based on world prices is complicated by the choice of whether to base the domestic equivalent of the world price on an export or an import parity price and by the high degree of instability in world commodity prices. If a country is a consistent importer, the import parity price for comparison with the farmgate domestic price would be the c.i.f. price plus transportation costs to the retail level minus transportation costs from farmgate to the retail level. If the country is a consistent exporter, the export parity border price would be the f.o.b. price in the world market, and the comparable domestic market would be the farmgate price plus transportation and other costs up to the f.o.b. level.

The decision to price a commodity on an export parity or import parity basis becomes more complex when a country is characterized by small deficits or surpluses in production of a commodity. Such a decision should be made on the basis of a careful examination of domestic production growth and the nature of the country's trade gap. In general, countries at the threshold of self-sufficiency may find it beneficial to use an average of export parity and import parity prices. This approach reduces the chance of unusual variability in prices resulting from the potentially wide gap between export and import parity prices.

The high degree of instability in world commodity prices poses a major problem for a policy of maintaining domestic prices in line with world prices. Few developing countries wish to import such high instability into domestic markets. Therefore, in the determination of domestic output price, using world price as a reference, an average world price can be utilized instead of the current world price. If the fluctuations in world prices are random, without an underlying trend, a simple average price would be appropriate. If the fluctuations in world price are accompanied by an underlying time trend, a moving average of world prices could be appropriate for guiding domestic price determination. In order to implement such policies, governments may use stabilization funds and stocking provisions, or variable tariff or quota systems. These policies are examined in more detail in the accompanying brief on stabilization policies.

CONCLUSIONS

Governments pursuing active price policies and intervening in markets can better do their job by adopting proper criteria and implementing them with consistent, well-designed measures. The use of world prices as a reference for input and output prices, although complex and imprecise, is socially optimal in the sense that the principle is consistent with efficient utilization of resources and maximization of productivity growth.

Setting domestic input and output prices in reference to the world price does not mean setting them equal to short-run world prices. Instead, it implies an alignment of the domestic price with the world price trend so that the effects of world price fluctuations can be minimized, and so that the short-run constraints associated with world pricing policies can be accommodated through selective interventions.

When a government intervenes to achieve policy objectives that call for long-term departures of domestic prices from world price trends, it should be fully cognizant of the possible social efficiency costs of these interventions and should consider alternative policies that may more directly address the objectives. The longer-run policy solution to many of the problems currently addressed through pricing interventions may lie in infrastructural development and the correction of market imperfections through such policies as the development of improved marketing information systems and financial institutions.

Price Stabilization in the Wake of Technological Progress

RAISUDDIN AHMED

An earlier brief on input and output pricing policy focuses on the question of appropriate levels of prices for agricultural inputs and outputs. The problems caused by instability in prices and the policies necessary to address them are examined here. What are the nature, extent, and cause of price instability? What effect does instability have on society? What approaches can be adopted to contain the problem? These questions constitute the essence of this brief. Foodgrain prices are of primary concern.

Two types of price variability afflict developing countries: intertemporal (seasonal and interyear) and spatial variability (price differences from place to place within a country). Intertemporal price variability is contained through public stocking policies, whereas the long-run solution of spatial variability calls for infrastructural development. Many African countries, however, use direct public procurement and distribution to reduce spatial price variability because infrastructure is underdeveloped.

Intertemporal stabilization of foodgrain prices is pervasive in developing countries, and measures have achieved some degree of success. For example, the coefficient of variation of the world price of rice was about 32 percent during 1974-85. In comparison, the coefficient of variation in rice prices in India was 11 percent; in Bangladesh, 12 percent; in Japan, 4 percent; in the Philippines, 6 percent; and in Colombia, 10 percent. But the cost of achievement has not been small. Bangladesh incurred a deficit of Tk 4.8 billion (US $150 million) on its public food account in 1989/90. India's total deficit in food and fertilizer was reported to average about Rs 75 billion (US$5 billion) a year during 1986-89. These costs imply forgone opportunity for long-run development.

But the reasons for stabilization of prices and supply are also quite compelling. In low-income developing countries, the poor spend more than half of their income on foodgrains. Any serious instability in prices causes severe disruption of their ability to purchase food, resulting in hunger and even starvation. Targeted food subsidy programs become too massive—administratively unwieldy, ineffective, and costly. In such countries, millions of small farmers produce foodgrains for both home consumption and sale with no insurance or effective credit markets. Under these conditions, risk and uncertainty arising from unstable prices act as a serious constraint to investment in agriculture. Moreover, the macroeconomic consequences of unstable food prices are by no means insignificant. Since foodgrains are the main wage good and weighted heaviest on the inflation index, instability in foodgrain prices invariably creates instability in macroeconomic variables, including political instability and labor unrest in industries. These important and comprehensive effects of price instability often escape measurement when using static economic frameworks.

Several factors in the agriculture of developing countries tend to accentuate price instability. As already noted, production on small farms is organized for both home consumption and market sale. Market sale becomes a residual activity after home consumption. This implies a much sharper fluctuation in market supply in response to production changes than would be the case in a completely commercial agriculture in which almost all quantities produced are marketed. Thus it has been estimated that a 10 percent change in production causes almost a 20 percent change in marketable surplus in Bangladesh. In a closed economy, when this change in marketable surplus is superimposed on low elasticities of demand and supply (0.4-0.5, for example), a 10 percent variation in production may be translated into a 40-50 percent variation in prices. Some of this potential volatility is of course contained by foreign trade and stock policies. Underdeveloped infrastructure also contributes to these forces. The scope of this price instability has been observed to increase during the phase of rapid technological progress in foodgrain production. In light of the relation between production and marketed surplus, on the one hand, and technological development and production, on the other, increased price instability in the wake of rapid technological progress is not surprising.

The foregoing discussion clearly leads to the conclusion that price stabilization is unavoidable in certain circumstances, but its costs must be kept to a minimum. Stabilization of prices should not destabilize the government budget. A stabilization program that allows private trade to operate within a normal profit band can be formulated without a major destabilization of the public budget.

A wide spectrum of price-band frameworks for stabilization of prices is available. At one end of the spectrum is the mechanism of variable tax and subsidy instruments. Under this approach, the foodgrain market is left entirely to private trade, but the government imposes a tax when the world price is low and a subsidy when the world price is high. This allows domestic prices to be partly insulated against world prices. But this approach does not give a feeling of security to highly vulnerable countries, because governments do not have public stocks to meet emergencies. Financial discipline to save money when taxes are raised and to give out money when subsidies are due is hard to

maintain in many low-income countries. Moreover, an oligopolistic structure in import and export trade may create some price instability in the domestic market. For these reasons, this approach, which is quite cost-effective, may not be acceptable to countries that are particularly subject to frequent food problems and widespread poverty.

At the other end of the spectrum is the public monopoly on imports and exports and government domestic price-band targets that are maintained through domestic open sale, procurement, imports, and a stock of foodgrains. Private trade is completely free to operate in the domestic market, and the price band limits government intervention to abnormal periods of foodgrain prices. IFPRI's research on price stabilization has demonstrated this approach for Bangladesh, Pakistan, and Kenya. An optimal stock policy and the pricing principles that link administered prices to market prices play critical roles in these models of price stabilization. In between these two extremes, it is possible to develop variants of stabilization approaches that would meet specific conditions of a particular economy.