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# Assessing the Impact of International Agricultural Research and Development Programs*

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**Summary.** — A number of studies are being conducted to assess the impacts of international agricultural programs. This "second generation" of impact studies can draw on earlier assessments of the production impacts of new, high-yielding rice and wheat varieties, particularly in Asia. New approaches and new data are needed, however, to assess the production impacts of other types of new technology (e.g., pest control methods, seed systems, and post-harvest technology) that are used with other crops and livestock, particularly in Africa and Latin America. Innovative study approaches are also needed to assess the institutional impacts of international programs. Given the high degree of institutional interdependence which characterizes agricultural research and extension it is inappropriate to attribute production impacts at the farm or consumer levels to specific international programs, as has sometimes been done. As an alternative to the narrow production economics framework employed in most previous impact studies, an interdisciplinary approach is outlined.

## 1. INTRODUCTION

The current environment of increasingly scarce resources for agricultural research and extension has spawned a number of "impact studies" which are intended to provide the donor organizations of industrial nations as well as policy-making groups in developing countries with measures of the value of international programs. The most ambitious and comprehensive of these is a study of the impact of the Consultative Group on International Agricultural Research (CGIAR).[1] Other organizations, including Canada's International Development Research Centre and the United States Agency for International Development, are also evaluating the impact of their agricultural projects.

The CGIAR has been in operation for more than a decade, and numerous bilateral agencies have supported agricultural programs for at least this long. Hence, it is understandable that many people are asking, "What have these programs accomplished?" "What has been their contribution to agricultural growth and development?" (*ex post* assessment) and "What can be expected in the future?" (*ex ante* assessment). Results of impact studies may influence the total allocation of funds to agricultural research and extension as well as the distribution of funds among different programs. Lessons drawn from the experiences of the multilateral and bilateral programs may influence the types of institutional strategies that are used in future agricultural programs. These institutional lessons may also be useful to groups outside of agriculture who wish to organize research networks in such areas as public health and population control.

The current impact studies — which I will term "second generation studies" — can draw on the methodology and empirical results of a substantial body of economic literature on agricultural research which includes hundreds of studies of

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the impact of new technologies.[2] However, most of the earlier, "first generation" studies were concerned with the development and spread of new varieties[3] and their impact on crop yields, production, and social welfare. The second generation studies are also concerned with the impact of international programs on research and extension capacity in developing countries. Methodologies for assessing these institutional impacts are notable for their absence in the first generation impact studies. Hence, the current studies face a considerable methodological challenge.

In estimating costs, benefits, and rates of return, most first generation impact studies employed rather simple economic models, heroic assumptions, and questionable data. In this paper I discuss some problems associated with these models, assumptions, and data, and present a case for broader, interdisciplinary approaches that, while perhaps less elegant or methodologically rigorous, are likely to produce results which are more useful for policy makers, research managers, and donor organizations. Throughout the paper I take as my point of reference the current concern for assessing the impacts of international programs, as contrasted to national or subnational programs.

Section 2 discusses the two distinct types of impact that must be assessed: production impact and institutional impact. Section 3 follows with a critique of the overly simplistic production economics framework and the data used in many previous impact studies. Section 4 reviews some difficulties involved in assessing the production impacts of three specific types of technology: pest management, seed systems, and storage. In Section 5, I turn to the most important, and generally neglected, sphere of impact for international programs: institutional impact. Section 6 treats the sensitive issues involved in attributing specific impacts to different international and national institutions. Section 7 outlines an interdisciplinary approach used by one international agricultural research center to assess the impacts of its research and training programs.

## 2. PRODUCTION IMPACT VERSUS INSTITUTIONAL IMPACT

In impact assessment, it is useful to distinguish between two types of technology that may be generated by an international agricultural research program — production technology and R & D (research and development) technology — and the corresponding two types of impact — production impact and institutional impact. "Production technology" refers broadly to all methods which farmers, market agents, and consumers use to cultivate, harvest, store, process, handle, transport, and prepare food crops and livestock for consumption. "R & D technology" refers to the organizational strategies and methods used by research and extension programs in conducting their work. "Production impact" refers to the physical, social, and economic effects of new cultivation and post-harvest methods on crop and livestock production, distribution, and use and on social welfare in general (including the effects on employment, nutrition, and income distribution). "Institutional impact" refers to the effects of new R & D technology on the capacity of research and extension programs to generate and disseminate new production technology.

Most impact studies to date have assessed the production impacts associated with new cereal varieties. While new varieties and complementary production technologies are of undeniable value, they are not the *only*, nor are they likely to be the most *important*, outputs of international agricultural programs. This is because production problems change over time, and national programs — not international programs — must solve most of them. The budgets of national programs represent about 95% of the total resources available for agricultural research in developing countries, and those of international programs only about 5% (CGIAR, 1985). A stream of new production technologies is needed to solve future production problems and maintain agricultural growth. Hence, R & D technologies that improve the capacity of national programs to generate new production technology can give international programs a substantial multiplier effect. Indeed, as Evenson (1977) and others have shown, the greatest beneficiaries of international agricultural research are countries with strong national programs. Because of the great variability of farming systems and production problems, national and subnational programs have a comparative advantage in generating production technologies, whereas international programs have a comparative advantage in generating R & D technologies.

R & D technologies include scientific procedures for genetic engineering, screening germplasm, disease identification and eradication, and rapid multiplication of vegetatively propagated crops. They also include organizational models, like the integrated commodity program, and institutional strategies for program planning and evaluation, training, "networking,"[4] on-farm trials, and interdisciplinary team research involving social and biological scientists.

The first international agricultural research

centers, CIMMYT and IRRI, produced new varieties of wheat and rice. However, shipments of seed — the classical, physical "technology transfer" — are now only one of several mechanisms used by international programs to distribute their research output. Even the "new seeds" produced by international centers are now best thought of as R & D technologies, rather than finished production technologies, since they are usually destined for breeding or screening programs rather than for immediate use as varieties by farmers (Dalrymple, 1979).

Perhaps the most important contribution of international programs is to set the tone for agricultural research in developing countries. In this respect, institutional strategies such as the multidisciplinary commodity program, on-farm research, and networking for germplasm evaluation, cropping systems studies, and other joint research ventures — all of which were developed through the collaborative efforts of international programs and national research centers — are now widely used in the developing countries.

The foregoing presumes that use of new R & D technologies will, in turn, generate improved production technologies. Many institution-building efforts have failed to produce either better institutional performances or improved technology. This highlights the need to examine the strategies and outputs of international programs and to carefully assess their impacts on institutional performance as well as production.

## 3. ASSESSING PRODUCTION IMPACTS

### (a) *The production economics framework*

Estimates of the impact of new technologies on production are useful in and of themselves and also because they are the starting point for assessments of other economic and social benefits at both the farm and aggregate levels (Hardaker *et al.*, 1984).

Impact studies to date have generally employed a production economics framework to assess the contributions of research to changes in agricultural output. The general argument, as stated in a proposal for the CGIAR impact study (CGIAR, 1984), runs as follows:

> The change in production of a particular commodity or farming system in a specified country over a defined period of time is measured; this change in production is to be explained in terms of the contributions of research and other influences. The major, distinct production systems, or production technologies, used by farmers are defined; at least one of these should be a new "new" technology — the product of agricultural R & D. An estimate of the relationship between the inputs and outputs (i.e., a production function) is estimated for each technology. The proportion of total output produced using each technology is estimated; this and the volume of total output imply a corresponding quantity of inputs used with each production technology. Accounting for the differences in outputs and inputs, the net economic and social benefits of the technologies can be estimated. The contribution of research is the difference between what the net value of output would have been in the absence of new technologies and what it actually was. This provides the basis for imputing the contribution of research to the observed change in output.

Data required for the analysis include: (a) estimates of changes in production in regions or countries over time; (b) knowledge of major production systems, including "old" and "new" technologies, and the proportion of total output generated by each; and (c) knowledge of production functions for each system. If distributional effects of technological change are to be analyzed, estimates of supply and demand elasticities are also required.

How adequate is this framework for assessing the production impact of new technology in developing countries? Let us look first at the data available.

### (b) *Time series data*

Each year, national estimates of production, area, and yield of most agricultural commodities appear in national statistical publications and in the *FAO Production Yearbook*. The quality of these estimates varies widely among commodities, countries, and variables. Estimates for developed countries, where sophisticated statistical agencies have operated for years, are generally far superior to those for most developing countries. The national statistical offices which provide figures to the FAO generally estimate the harvested area and production of each crop, and calculate yields based on these two variables. Consequently, errors in estimating area and production are compounded in the published yield figures.

It is costly to compile and assure the accuracy of data on crop production, harvested area, and yield. Hence, statistical agencies tend to concentrate their effort on those commodities for which the information has most value for public and private sector decision-makers. These are generally considered to be the "big dollar" crops and livestock products which are traded on international markets.

Production and yield estimates for roots and tubers, vegetables, and other crops which are grown in remote areas and consumed on the farm or traded locally tend to be poorer than estimates for cereals, oilseeds, sugar, and other crops which are traded on international markets. The FAO has published manuals with crop-cutting techniques for estimating yields of the major cereals, but no "crop digging" methods have been published for root crops, such as potatoes. In some cases, errors and revisions of the statistical series are staggering. FAO estimates of China's potato production were for example, revised *downward by* 70% in 1978 and then revised *upward again* 230% in 1983. These revisions had a substantial impact on estimates of total potato production in the developing countries. The 1983 revision amounted to an increase of 35 million tons of potatoes — more than the total estimated potato production in the other 90 developing countries combined! China is not the only country with controversial statistics. Similarly differing estimates have been reported for potato production in Zaire and the Philippines[5] (Horton *et al.*, 1984).

Careful analyses of time series estimates for other crops and livestock[6] are not available, but it is likely that careful scrutiny would uncover similar errors and biases, particularly for non-traded, "minor" crops (e.g., root crops, vegetables, pulses) and livestock products.

Aside from the basic issue of accuracy, national-level estimates also mask important variations within countries, between production zones and different types of producers. Since farmer adoption and the production response of new technologies are highly location-specific,[6] data which are disaggregated along the lines of major production zones are necessary for meaningful assessment of impact but seldom available.

It seems reasonable to conclude that while available time series may reflect the approximate magnitudes and basic trends in crop and livestock production, they are poor sources of data for impact assessment.

### (c) *Production systems*

In recent years farming or cropping systems research has come to be seen by many as a useful complement, or in some cases an alternative, to research on component technologies. The volume of publishing in this field has mushroomed (Casement, 1982). Unfortunately, however, surprisingly few studies actually describe and explain the logic of how farmers grow their crops and tend their livestock. General portraits of study areas, project activities, field methods, preliminary results, and recommendations are the rules; description and analysis of technology the exception.[7]

Detailed cropping systems reports are available for rice production in some parts of Asia (IRRI, 1982), and a few studies are available for other crops, particularly those grown over large areas as sole crops. But little has been published on the technology used for most crops and livestock grown on small farms, particularly in marginal, semi-commercial areas. Rarest of all are analyses of how production systems have changed over time in response to the introduction of new technologies. Even in the cases of rice and wheat production in Asia, detailed descriptions of farmer's practices before and after introduction of high-yielding varieties are rare.[8] Hence, many assessments of the impact of new varieties rely more heavily on experimental results and economic models than on empirical studies of changes in farmers' production systems.

In the specific case of root crops, there are still no reasonably accurate maps indicating *where* these crops are grown in the tropics, much less descriptions of *how*. Analysis of root crop production systems is hampered by the fact that these crops are grown under an extremely wide range of ecological conditions, and they are often produced and consumed by minor ethnic groups in remote areas which are not well integrated into the market economy (Horton *et al.*, 1984).

National or regional surveys occasionally provide data which can be used to estimate the spread and production impact of new technologies or production systems. A few Asian countries' statistical agencies report use of "modern" or "high-yielding" cereal varieties and the resulting production. For other areas, crops, and technologies, however, few "hard" data are available on which to base aggregate estimates of the diffusion of new technologies and the share of total production contributed by old and new production systems.

Even in the case of cereal varieties, many estimates of returns to agricultural research are handicapped by the difficulty of identifying "new" and "old" varieties. Terms like "IRRI varieties," "high-yielding varieties (HYV)," and "modern varieties" although often used are seldom clearly defined. The principal source of data on the spread of HYV of rice and wheat is a series of reports authored by Dana Dalrymple issued by the United States Department of Agriculture in cooperation with the Agency for International Development (sixth edition, 1978). Dalrymple's estimates are based primarily on

data provided by AID country missions and USDA agricultural attachés. These data, in turn, were usually obtained from official reports or estimates by the countries themselves. As the author notes, "While the data have been checked as far as possible, there is really no good way of knowing how accurate they are" (Dalrymple, 1978, p. 5).

For other crops, the problems of estimating use of new varieties are greater. Bangladesh, for example, has recently published official statistics of farmer use and yields of "HYV of potatoes." It is generally assumed that HYV of wheat and rice are in some sense a product of the breeding programs of CIMMYT and IRRI, and by the same logic one might assume that the HYV of potatoes are a product of the breeding program of the International Potato Center (CIP). However, this is not the case. What Bangladesh's statistical reports consider HYV of potatoes apparently include all varieties recently introduced from abroad, mostly from Europe. How recently they have been introduced, and the specific criteria used to distinguish them from non-HYV are not clear. Hence, the proportion of potato output generated by HYV's would clearly overstate the contribution of CIP's breeding program to Bangladesh's potato production. To the extent that this type of definitional problem occurs with wheat and rice, previous impact assessments based on official statistics might have exaggerated the use and production impact of varieties associated with IRRI's and CIMMYT's breeding programs.

### (d) *Production functions*

Production function analysis, now considered "old hat" by agricultural economists in the developed countries, has never been widely applied in most developing countries. Again, irrigated rice in Asia presents an exception to the norm. For most other crops and regions little production function anlysis has been done. This is partly due to the complexity of modeling farming systems in developing countries and the lack of necessary data (Anderson and Hardaker, 1979). It is also due to limitations of computer hardware and software and to the low priority assigned to farm management-type research. In Latin America, for example, where the social sciences, including economics, are macro-oriented and highly politicized, farm management courses are seldom taught. Moreover, there is little incentive for students or professional economists to do the fieldwork necessary for meaningful production function analysis.

Impact assessors may wish to do their own production function analysis, based on results of farm surveys or experiments. How adequate are these sources?

#### (i) *Survey data*

Rather than estimates of response surfaces, the best that can be obtained for most crops and areas are single-point cost-of-production estimates which may be gleaned from documents of ministries or agricultural banks.

Unfortunately these often reflect *recommended*, rather than *actual*, farming practices. They may be "guestimates" based on no fieldwork whatever. Where they draw on farm surveys conducted by government employees — usually extension agents — they may be misleading because exetension workers generally interview their clients: larger-than-average farmers in accessible, commercial areas (Horton, 1984; Rhoades, 1982a, b). These farmers usually constitute a small minority of the rural population, whose production practices often differ sharply from those of most producers. A 1974 survey conducted by extension agents in highland Ecuador illustrates this point. Survey results indicated that over 50% of all potato producers used credit from the government's agricultural bank. From the bank's own records and census reports, however, it was clear that no more than 5% of the area's potato farmers used bank credit. The reason for this discrepancy was that the extension workers who conducted the survey had interviewed only their "contact farmers" (Valderama and Luzuriaga, 1980). Another problem of official estimates is that they generally include fictitious costs for such items as minimum wages and social security payments, which are not, in fact, paid by farmers.

Survey results from the Mantaro Valley of Peru's Central Highlands show how markedly technological coefficients can vary between three groups of farmers in a single agro-ecological zone (Table 1). Production cost estimates available from Peru's Agrarian Bank and Ministry of Agriculture approximate the survey estimate for large farmers who constitute a small minority of potato growers in the area.

#### (ii) *Experimental data*

As an alternative to time series and survey data, experimental results are sometimes recommended as a basis for estimating the impact of technological change on crop yields. In practice, available experimental data seldom reflect the performance of alternative technologies under actual farming conditions. And for obvious reasons impact analysts seldom have the luxury of being able to design the needed experiments

Table 1. *Input use, yields, and use of output for three size groups of potato producers in the Mantaro Valley, Peru*

| | Unit | Farm size | | |
|---|---|---|---|---|
| | | Large | Medium | Small |
| *Input* | | | | |
| Labor | day/ha | 175 | 124 | 136 |
| Oxen | day/ha | 4.4 | 9.4 | 13.6 |
| Tractor | day/ha | 5.6 | 2.6 | 0.5 |
| Seed | ton/ha | 1.8 | 1.2 | 1.0 |
| Fertilizers | | | | |
| Manure | ton/ha | 7.1 | 5.4 | 11.0 |
| Nitrogen | kg/ha | 330 | 184 | 92 |
| Phosphate | kg/ha | 141 | 122 | 5 |
| Potash | kg/ha | 128 | 84 | 30 |
| Insecticides | | | | |
| Soil | kg/ha | 36 | 22 | 74 |
| Foliar | liter/ha | 4.9 | 3.0 | 0.4 |
| Fungicides | kg/ha | 4.5 | 16.5 | 0.8 |
| Yield | ton/ha | 21.8 | 9.4 | 3.3 |
| Percent of output sold | % | 75 | 40 | 0 |

Source: Horton *et al.* (1980).
Note: All farms are in the "Low Zone," a riverine plain along the Mantaro River. In the production season under study (1977/78) "large farms" harvested an average of 4.3 ha of potatoes, "medium farms" 1.1 ha, and "small farms" 0.3 ha.

and wait several months or years until results become available. Little can be expected from the first cycle of experiments, aside from useful training for those who are experimenting (Horton, 1984). A number of years of interdisciplinary research, including farm-level trials, farm surveys, and direct observation, are generally needed to obtain accurate information on technological change and its true impact on yields, costs, and returns. The limitations of available experimental results are illustrated in the following example, drawn from Fano (1983):

> By developing-country standards Peru has a long history of potato research, dating from the 1940s. Several thousand potato experiments have been conducted both on the coast and in the highlands. Most of these have included new varieties and most have been on farms, rather than on experiment stations. Based on these facts, it was assumed that experimental data could readily be located to document the effect on yield of changing from an old to a new variety of potatoes. (The hypothesis was that the resultant increase in yields would be greater on the coast, where growing conditions, particularly irrigation, were more favorable than in the highlands.) In an exhaustive review of literature in Peru's Agrarian University and the country's leading experiment station, a large number of publications were found which reported the experimental yields of new potato varieties, but only four reports were found which compared experimental yields of both old and new varieties, and none of these provided an indication of the levels of non-experimental variables, such as fertilization, pest control, and seed quality.

Many institutions have recently begun to conduct specialized experiments on farmers' fields to quantify the yield differentials associated with alternative technologies. The International Agricultural Research Centers have played an active role in stimulating this work and developing methodologies for it.[9] Results of on-farm experiments are useful for many purposes, but they are often misleading for impact assessment, because they exaggerate the yield increases which farmers would actually attain if they switched from their present technology to a new one (Horton, 1984; IRRI, 1977).

There are four sources of this experimental bias in favor of new technology. One is that on-farm experimenters often attempt to prove they can do better than the farmer. This is illustrated by a personal observation in the

Mantaro Valley, Peru. An on-farm experiment was designed to measure the yields, costs, and returns associated with two sizes of potato seed tubers: the recommended size and the farmer's present size (presumably smaller). In a yield visit, I observed the researcher sorting a farmer's seed into two size groups: large and small. He planned to use the larger seed tubers as the "recommended technology," in the experiment and the small seed tubers as the "farmer's technology." Since the farmer would have planted the entire seed lot, with both large and small tubers, what the researcher was defining as the farmer's technology in the experiment was inferior to the farmer's real technology. In effect, the researcher was stacking the cards against the farmer. Based on numerous similar observations, I believe this is quite common in on-farm experimentation.

A second, less obvious but nontheless important, source of bias stems from the fact that yields measured on small experimental plots generally exceed those on large fields, even when the same technology is supposedly used. In fact, the technology applied to experimental plots and farmers' fields is seldom really the same: more care is taken and more labor and capital are generally applied on small experimental plots, and the harvest tends to be more thorough than it is on farmers' fields.[10] Experimenters also tend to locate experimental plots on better-than-average land — the best parts of the field. If yields on experimental plots that are designed to simulate the farmer's and a new technology are both the same *proportion* over what they would be on farmer's fields, the *absolute* yield gap between the two technologies is larger on small experimental plots than on farmers' fields. Moreover, because most experiments are conducted on better-than-average land, where new technologies like high-yielding varieties can best express their production potential, the yield gap between old and new technologies is likely to be greater in both absolute and proportional terms.

A third source of bias comes from the methods used by researchers to reduce sources of variation among experimental sites by standardizing the levels of non-experimental inputs at assumed "normal," "representative," or "average" levels. More often than not, these standardized levels are above-average. Hence, all the treatments in the experiment, including the "farmer control" treatment, yield far more than they would have if non-experimental inputs had been left at the farmer's level. For reasons mentioned above, elevating the level of non-experimental inputs generally has the effect of increasing the measured yield gap between what are considered to be (but are not, in fact) the farmer's own technology and the new technology.

A fourth source of bias occurs when researchers do not include a farmer control treatment in their on-farm experiments, but simply compare the experimental yield of the new technology against the yield of a "representative" farmer's crop or the average yield for the area. Results of this type of comparison generally show a dramatic, but highly exaggerated, yield advantage in favor of the new technology.

These biases help explain why farmers often do not adopt technologies that are recommended on the basis of experimental results. They also imply that impact assessments based on experimental results may overestimate the benefits of new technologies. In this respect, Scobie's (1979) estimate that adoption of HYV rice and wheat led to average yield increases of 50 and 100% respectively, is based on yield comparisons from both experiment stations and on-farm trials, which the author gleaned from over 100 secondary sources. In view of the substantial "yield gaps"[11] between experiment stations, on-farm trials and farmers' fields, it seems reasonable to conclude that the experiment station results used by Scobie almost certainly overstate the yield increases actually obtained by farmers. The results of on-farm trials probably did so as well.

Less frequently, an economic analysis based on experimental results *underestimates* the profitability and production impact of a new technology. An example is provided by a seed potato storage project in the Philippines. Experiments and economic analysis indicated that the new storage technology was not likely to be adopted because it increased yields only by a small margin. Farmers adopted the technology, however, because it extended the period over which they could store their seed and hastened emergence of the subsequent crop. Hence, because they did not understand the farmers' motives for using a new technique, evaluators had underrated its potential benefits.

The change in yields resulting from adoption of HYV has been the central variable in most impact assessments. Many new technologies, however, are adopted by farmers not because they increase yields, but because they reduce costs, increase quality, or allow crops to be planted in new areas or at different times of the year. Such technological improvements may generate substantial benefits for producers or consumers even if they are lower yielding.[12]

The conclusion here is not that costs and benefits associated with technological change cannot be captured in economic analyses of experimenal results, but that in many cases they

*have not been* captured adequately. For impact assessment — *ex post* and, particularly, *ex ante* — more detailed knowledge of farmers' physical and socioeconomic environments, decision-making processes, and technologies is needed than has generally been recognized.

### (e) *Demand elasticities*

Estimates of supply and demand elasticities are necessary for partitioning, quantitatively, the benefits of technological change among producers and consumers. However, these elasticities have not been estimated in most developing areas for most foods. Due to the lack of time series of food prices and consumption and the sheer complexity of incorporating price variables into econometric estimations, most demand projections for agricultural commodities ignore price effects.[13] In the absence of elasticity estimates for practically all food crops but wheat and rice in developing countries, there has been a tendency to assume that the relatively low elasticities observed in Western Europe and North America apply in developing countries as well. Since incomes are lower in developing countries and food constitutes a much higher share of household expenditures, this is unlikely. The few empirical studies which have been done indicate that price elasticities of demand tend to be substantially higher in developing countries than in Western Europe and North America (Timmer *et al.*, 1983).

Another problem with available elasticity estimates is that in the case of "miscellaneous," "starchy," or "minor foods," publications generally present average estimates for several commodities. Lumping such diverse crops as potatoes, cassava, yams, sweet potatoes and bananas together under the single heading, "starchy foods," has certain advantages in reducing the size of tables, and the costs of editing, printing, and distributing publications, but there is no economic basis for it. These foods often play quite different roles in the diet. For example, in many areas where cassava is a low-cost staple food with inelastic demand, potatoes are a high-cost vegetable with highly elastic demand (Horton *et al.*, 1984). Consequently, no single elasticity can reflect the true association between price changes and the level of consumption of any one of the foods in this miscellaneous category.

## 4. WHICH IMPACTS TO ASSESS

Use of production economics to quantify the impacts of technological change is most straightforward where: (a) the physical environment (e.g., relief, soils, and weather) is uniform across all observation points; (b) the production process generates a single output and employs few variable inputs; (c) inputs and the output are easily quantifiable and uniform in quality; and (d) all inputs are purchased and the output is sold. If the number of variable inputs and outputs is large, their quality is variable, and production is partially or wholly subsistence-oriented, impact assessment using a production economics framework becomes complex and its results are influenced by a large number of simplifying assumptions of dubious validity. In some cases — like the use of experiment station yields as a proxy for farm-level results — simplifying assumptions lead to overestimation of production impact. In other cases, such conservative assumptions may be made, to compensate for questionable data, that studies underestimate rates of return.

### (a) *Varieties vs other technologies*

Such variables as yield (as the dependent variable) and fertilizer level and variety (as independent variables) fit the data requirements of production function analysis quite well, particularly in highly commercialized, irrigated areas. Yields and fertilizer levels enter the production function as quantitative variables, and variety as a dummy variable. Data on use of new and old cereal varieties, fertilizer levels, and yields are most readily available in Asia. This is also the region where university training in production economics is most advanced. Hence, it is not surprising that production function analysis has been used most widely for assessing the impact of new cereal varieties in Asia. After variety, fertilizer level and irrigation have received most attention in adoption and impact studies. This is appropriate, since the new, semi-dwarf varieties are much more responsive to increased fertilization under irrigation than is the case of older varieties.

But what of improvements in other technologies, other crops, and other areas? Have they not occurred, or have they been overlooked? Field observations and available statistics indicate that increases in production and yields of some other crops, such as potatoes, have been on par with, or not far behind, the increases for wheat and rice (Table 2). In the case of potatoes, the crop I know best, technological improvement has been rapid not only in the use of new varieties but also in pest control, seed systems and post-harvest technology.[14] These

Table 2. *Value of production of 10 principal food crops in developing countries and average annual change in yield from 1961/65 to 1981/83*

| | Number of producing countries | Production ($10^6$ t) | Farm-gate price (\$/t) | Value ($10^6$ US \$) | Average annual change in yield (%) |
|---|---|---|---|---|---|
| Rice | 93 | 404.0 | 170 | 68,680 | 2.1 |
| Wheat | 66 | 179.5 | 148 | 26,566 | 3.4 |
| Maize | 115 | 155.6 | 119 | 18,516 | 1.6 |
| Potatoes | 91 | 82.3 | 142 | 11,687 | 1.8 |
| Cassava | 92 | 127.4 | 70 | 8,918 | 0.5 |
| Sorghum | 66 | 47.3 | 123 | 5,818 | 3.1 |
| Tomatoes | 97 | 21.5 | 195 | 4,193 | 2.0 |
| Millet | 51 | 27.2 | 144 | 3,917 | 1.1 |
| Yams | 41 | 24.0 | 163 | 3,912 | 1.2 |
| Plantains | 42 | 20.0 | 114 | 2,280 | n.a. |

Sources: Number of producing countries: corresponds to 1980, derived from FAO (1981). Production: average for 1981/83, derived from FAO (1984). Farm-gate price: weighted average for all developing market economies, provided by FAO Basic Data Unit (unpublished). Value: production multiplied by farm-gate price. Average annual percent change in yield: corresponds with 1961/65 to 1981/83, derived from FAO (1984 and 1977).

changes have not been assessed for two reasons, it seems: First, analysts have focused on tradeable commodities, like wheat and rice, and assumed that potatoes are unimportant in developing countries. However, as shown in Table 2, potatoes are among the most important crops grown in developing areas in terms of the number of producing countries and the monetary value of production. A second reason, elaborated below, is that the impact of changes in pest management, seed systems, and potato storage are less well understood and more difficult to assess than is the impact of a new variety.

(i) *Pest management*

Pest management practices are changing rapidly in many farming environments, but data on changes and their socioeconomic impacts are difficult to obtain. Farmers' pest management strategies are extremely complex, and involve important qualitative variations in both inputs and outputs. Moreover, detailed understanding of the biology of pests as well as farmers' control measures is required for impact assessment.

Before the economic impact of changes in pest management can be measured, an understanding of farmers' pest problems, management strategies, and of whether the influence to change comes from public or private agencies, or from neighbors, is needed. This would require in-depth, multi-disciplinary farm-level research which has not been done.[15]

(ii) *Seed systems*

Potatoes can be multiplied sexually through use of true potato seed, but with few exceptions, farmers the world over plant tubers — generally 1–2.5 tons per hectare. In most developing areas, these "seed tubers" are the single most costly input in potato production, and poor seed quality — referring to a constellation of factors, including disease level, physiological condition, and size of tubers — is one of the potato crop's most important yield constraints. Variations in seed source often confound results of variety trials and other experiments, since the impact of seed quality on yield can be greater than the impact of variety. As illustrated in the following example from Monares (1984), assessing the impact of improved seed systems, which embody both technical and institutional innovations, calls for a rare combination of biological, economic, and institutional knowledge and analytical skill.

Rwanda's National Potato Improvement Program (PNAP) established in 1979 uses simple techniques to supply farmers with improved quality seed. Without postharvest virus testing facilities. Rwanda's seed production system depends primarily on field observation of plant vigor and the proportions of healthy and diseased plants. The seed program now produces about 250 tons of seed per year of which about 50% is of new Rwandan varieties.

The result is an increasing number of Rwandan farmers with access to improved seed which gradu-

ally replaces old, degenerated varieties. Production of improved seed is still significantly lower than current farmer demand for seed. Yet, reports from seed projects and preliminary surveys indicate that about 7,000 hectares, representing nearly 20% of the total potato area, are now planted with seed originating from the national seed program.

PNAP conducts on-farm research trials to gauge the performance of its improved seed. The average yield increase on farms due to use of improved seed is estimated to be about 3 tons per hectare — a 40% increase over traditional seed. Newly selected varieties often yield twice as much as common farmer seed in on-farm trials.

The program is expected to continue operating at the same scale, and its costs will remain at about the same level while benefits increase significantly as cultivation of new varieties spreads. Given the slow virus degeneration rate, the multiplier effect of a small stock of clean seed is great.

An economic assessment of Rwanda's seed program would require quantitative estimates of: (a) the performance of improved seed under existing farming conditions and (b) the seed degeneration rate (yield reduction over time from virus infection). An understanding of the institutions involved in seed production and distribution would also be needed to estimate present and future streams of costs and benefits. Separate assessments of the impacts of new varieties and improved seed — two quite distinct innovations — would require much more detailed information and a more complex analytical framework.

(iii) *Storage*

Problems of storing table potatoes have preoccupied developing country policy makers and scientists for decades, but seed storage has received little attention. There are reasons why table potato storage has received so much attention. First, violent fluctuations in potato prices and wide price spreads between farm-gate and retail prices have been interpreted as evidence of market imperfections and the need to regulate the distribution of potatoes via market interventions and storage. Second, since farmers and processors in developed countries generally store table potatoes, it has been assumed that their developing-country counterparts could also benefit from doing so. Third, it has been assumed that developed-country storage technology could readily be "transferred" to developing countries.

In fact, there is little economic basis for storing consumer potatoes in many developing areas. This is because harvests occur throughout the year and there is no assurance that price will rise after any given harvest. Potato storage in the tropics is also much more costly and risky than in temperate zones. As a consequence, most potato storage schemes in developing countries have failed.

In contrast to the situation with table potatoes, and despite the general lack of political and scientific interest in the topic, storage of seed potatoes is a major concern of potato growers in most developing areas. This reflects farmers' desire to avoid purchasing seed tubers, which are costly and often poor in quality. Purchased seed often carries seed- and soil-borne diesease, some of which (e.g., bacterial wilt, *Pseudomonas solanacearum*) can have a devastating effect on yields and remain in soil for years. Additionally, seed tubers in appropriate physiological condition for planting — with their "eyes open" — may not be available on local markets when farmers would like to plant. The following Sri Lankan example, derived from Rhoades (1985) illustrates the types of diverse impacts which can result from improvements in seed potato storage.

Potatoes are grown in Sri Lanka during different months in distinct agro-ecological zones of three main districts: Jaffna, Badulla, and Nuwara Eliya. The last two of these, which account for about 80% of the growing area and 90% of national production, have two main production seasons: *yala*, referring to the southwest monsoon which lasts from mid-May to mid-September, and in this paper is termed "early," and *maha*, referring to the northeast monsoon which lasts from October to mid-January, designated here as "late."

Until 1979, the government allowed importation of foreign seed for both early and late seasons. Due to difficulties in obtaining seed, and government targets of reducing imports, a decision was reached in 1979 to stop importation from Australia for the early season. The only importation allowed now is European seed for the late season, thereby creating a serious shortage of seed for the early season.

The diffused light storage (DLS) technique is based on using natural indirect light instead of low temperatures to prolong seed storage and control excessive sprout growth and storage losses. A Sri Lankan scientist and an extensionist were trained in DLS technology in courses in the Philippines. Upon their return to Sri Lanka, they set up experiments and farmer demonstrations in Badulla and Nuwara Eliya.

From 1979 to 1983 Sri Lankan farmers build more than 500 diffused light stores, and another estimated thousand farmers modified their existing storage system. Farmers seldom copied demonstration models, but modified them to meet their own needs and budgets. Many farmers integrated diffused light storage principles into existing sheds, garages, and rooms attached to their houses.

In a 1984 survey, adopting farmers noted the following benefits of the DLS system: (a) sprouting is reduced and seed can be stored longer; (b) storage losses are reduced; (c) pest control is easier;

(d) field emergence of seed stored in diffused light is earlier, and the growing season is shorter; (e) yields are higher; and (f) seed is now available for October planting. In addition, farmers pointed out that seed tubers stored in light sell for a higher price than tubers stored in darkness.

As this example illustrates, an economic assessment of what might appear to be simple improvements in seed storage may incorporate a large number of qualitative changes in both inputs and outputs. The methodological problems are by no means insurmountable, but they do require more detailed analysis than is needed for economic assessment of the impact of a new variety.

Clearly as one moves away from assessing impact of new cereal varieties, the production economics framework serves less well, and more information is needed on farmers' practices, the nature of changes (in qualitative as well as quantitative terms), and the institutional mechanisms responsible for them.

## 5. THE ATTRIBUTION OF IMPACT

Attribution of the impacts of agricultural R & D to different institutions is one of the most sensitive issues of impact assessment. Evenson (1977) Boyce and Evenson (1975), Evenson and Kisler (1975) and others have emphasized the interaction effects of national and international research. Yet, many developing-country scientists and policy makers feel that impact studies have failed to recognize important contributions made by their institutions.

Few, if any, new technologies are generated *solely* by international programs or reach farmers without substantial contributions from national research and extension programs. Hence, it is inappropriate to attribute production increases and associated benefits solely to the work of bilateral or multilateral programs. This has generally been acknowledged in the introductory sections of publications assessing the impacts of agricultural research (see, e.g., Dalrymple, 1978, pp. 3–5). Nevertheless, the conclusions of these same studies have often been interpreted as overemphasizing the role of international programs *vis-à-vis* national programs. Perhaps more importantly, the popular press has disseminated the notion that production increases have been due solely to the good work of international agencies. This has tarnished the image of international programs in many developing countries.

Great care is needed to ensure that impact studies give due credit to the various contributors, which in addition to national programs in developing countries often include bilateral agencies, foreign universities, and farmers themselves. The following example, derived from Franco and Schmidt (1985) illustrates how complex the chain of causation can be:

In the early 1970s the Peruvian Ministry of Agriculture requested that CIP help combat a serious outbreak of bacterial wilt in potato crops in northern Peru. To this end, CIP obtained resistant breeding lines from the University of Wisconsin. These lines had been developed from potato samples sent to Wisconsin by the Colombia's National Agricultural Research Institute (Instituto Colombiano Agrario: ICA). Researchers employed by CIP and the Peruvian Ministry selected potential new varieties on government experiment stations in northern Peru. Two resistant varieties were released by the Ministry of Agriculture in the mid-1970s. One of these, called "Molinera," is now among the most widely grown potato varieties in northern Peru. From advanced variety trials, Peruvian farmers also kept and multiplied at least two other clones which are now grown in the area. One has gained such importance that it was recently named and officially released as a Peruvian variety.

Such multiple causation seems to be the norm rather than the exception in agricultural research and extension. In the examples cited earlier from Rwanda and Sri Lanka, and in most other documented cases I know of, similar processes of multiple causation were responsible for the final outcomes.

One could perhaps arrive at valid procedures for separating and quantifying the impacts of different institutions. But, aside from being difficult, it would seem more appropriate to share the credit and emphasize that successful programs are based on collaboration, rather than unilateral efforts.

## 6. ASSESSING INSTITUTIONAL IMPACTS

International agricultural programs represent small but strategic components of the global agricultural R & D system. As noted in Section 2 of this paper, international programs are suppliers of R & D technology rather than production technology *per se*. They can have the following types of institutional impact:

1. Strengthen agricultural R & D programs in developing countries, through training, supplying research information.
2. Stimulate research institutions in developed countries to address problems which are important in developing countries.
3. Link national programs to the global R & D system, through improved communica-

tions, collaborative research, conferences.
4. Contribute to establishment of priorities in key research and policy areas.
5. Inform donors and stimulate their continued support.

The methodological problems of assessing these various influences and assigning monetary values to them seem insurmountable, particularly in view of the resources and time frame of most impact studies. Before these impacts can be *measured*, it is necessary to first *understand* the types of impacts being achieved and the institutional strategies used to achieve them. Providing documentation in these areas is one of the most valuable potential contributions of the second generation of impact studies.

There is no analytical framework for assessing institutional impacts which is analogous to the production economics framework for assessing production impacts. The inputs and outputs of international R & D programs are too numerous and qualitatively variable to be analyzed within a single econometric model. Moreover, the policy environments in which these programs operate significantly affect their institutional performance and impact.

Needed are assessments of the strategies used by different centers and the results obtained in different settings. Given the diversity of strategies and types of impact and the lack of information on these topics, there is no practical alternative to a case study approach. Case studies should document impacts in the four areas identified earlier in this section.

## 7. CIP IMPACT STUDY

In a study recently conducted by the International Potato Center (CIP, 1984) an attempt was made to avoid some of the conceptual and methodological problems of earlier impact assessments. Responsibility for preparation of the study was given to an interdisciplinary team of professionals, rather than a team of economists. Scientists and policy makers from developing countries were actively involved in preparing the study, which assessed both production and institutional impacts. Rather than focus on econometric estimation of the production impact of new varieties, the CIP study describes and illustrates a range of types of impact as well as the institutional strategies used to achieve them. Recognizing the significance of collaboration and multiple causation, the study made no attempt to attribute specific, farm-level impacts to CIP.

The study's three major sections are:

1. A description of the strategies employed in program planning and review, interdisciplinary team research, institutional linkages, and training.
2. A review of the Center's research program and its results to date.
3. Case studies which illustrate how problems of potato production and use have been solved and diverse types of institutional and production impacts achieved.

The case illustrate various types of impact, ranging from training and institution building, to yield increases, to the development of an effective model for interdisciplinary problem-solving.

Preparation of the CIP study was coordinated by an economist (this author), but involved taxonomists, breeders, pathologists, entomologists, nematologists, physiologists, seed specialists, research managers, policy makers, and communication experts, as well as economists, sociologists, and anthropologists. Major sections of the final report were drafted by biological scientists. Three of the seven illustrative cases were prepared by biologists, two of whom were national program scientists. Two other cases were prepared by an anthropologist, and two were written by economists.

Involvement of scientists and policy makers from developing countries helped focus the study on those problems and accomplishments which CIP's clients considered to be the most important. Individuals from several parts of Africa, Asia, and Latin America, as well as Europe and North America provided frank and critical appraisals of the Center's programs, accomplishments, and shortcomings. A selection of their comments are presented in the study report.

Assessments of institutional impacts required information on CIP's interaction with national programs and the resulting effect on national R & D capacities. Three distinct approaches were used to obtain and synthesize the needed information. Initially, country-level information was recorded by CIP's regional scientists on a brief questionnaire requiring simple yes/no answers.[16] The information obtained covered such topics as: frequency of CIP contacts (correspondence and visits) with each national program; participation in various types of training and seminars; distribution of research reports; collaborative research projects and/or research contracts in each country; use of CIP-related technologies in national R & D programs and on farms.

This country-level information was complemented with more precise, quantitative data gleaned from the Center's files on training and collaborative research efforts, and their impacts on production and institutional capacity.

The third approach involved preparation of seven case studies which illustrated both the strategies and impacts. The first case describes CIP's relations with its host country, Peru, emphasizing the relationship's reciprocal nature and the resulting benefits. The second case documents how, through trial and error, a team of postharvest technologists and anthropologists developed an interdisciplinary model, known as the "Farmer-Back-to-Farmer" model, which helps researchers identify and solve farmers' problems in the shortest possible time (Rhoades and Booth, 1982). The third case, from Vietnam, illustrates how an international agricultural research center can learn from a developing country's innovations, and incorporate this knowledge into its own research and training programs, to the benefits of other countries. The fourth case presents an economic assessment of a seed multiplication program in Tunisia. The fifth case documents the rapid establishment of a research and extension program in Rwanda, and presents an economic assessment of the new program's impact. The sixth example, from Sri Lanka, illustrates how innovations in one key element of the potato production system — seed storage — can have far-reaching effects on planting and harvesting dates, yields, the intensity of cropping systems, production costs, foreign exchange expenditures (for seed potatoes) and potato prices. The seventh case describes the operation of a regional collaborative research network in Central America and its impact on the research priorities, staffing and performance of the national potato programs and the linkages and flow of information between them.

Those who are interested in the broad range of types of technological and socioeconomic impacts that international and national programs can achieve and the strategies used to achieve them should find much of interest in the CIP study. Those looking for cost-benefit analyses and rates of return to specific research activities may be disappointed, since these are presented in only two of the study's seven cases.

## 8. CONCLUSIONS

The impact of agricultural research in developing countries has been assessed primarily in terms of the production impact: the economic value of output increases associated with new wheat and rice varieties in Asia. This was a logical consequence of the great public and scientific interest in the "Green Revolution." It also reflects the relative abundance of information on rice and wheat production in Asia and the relative simplicity of assessing the economic impact of new varieties. It seems likely that research and extension programs have generated many other types of impacts, but these have, by and large, been overlooked.

Most impact studies contribute to one or more of the following biases in the economic literature on agricultural research:

1. The magnitude of technological change in *wheat and rice production in Asia* is exaggerated, relative to the changes which have taken place with other commodities in other regions.
2. The significance of *new varieties* is exaggerated, relative to other types of technology.
3. The importance of *yield increases* is exaggerated, relative to other attributes of new technology.
4. *Too much credit is given explicitly or implicitly to international programs*, relative to other sources of change, including the research and extension programs of developing countries.

The unique contribution of international programs to agricultural development is to supply R & D technology which improves institutional performance, rather than production technology which raises productivity at the farm level. International programs play a strategic role in disseminating research findings, methodologies, and institutional strategies that national programs can use to generate finished technologies for farmers. Hence, the impact of international programs should be assessed primarily in institutional terms, not in terms of production increases at the farm level.

Previous studies have seldom assessed institutional impacts, and the production economics framework has several limitations in this regard. Hence, the current generation of impact studies needs to be particularly innovative in its institutional analysis. Methods such as key informant interviewing and case studies which are needed for assessing changes in complex organizations, are outside the bounds of traditional economics. Hence, professional contributions are needed from other disciplines, like anthropology, sociology, and management. To ensure that impact assessments reflect the values and perceptions of scientists and policy makers in developing countries, it is necessary that they be involved, not merely as sources of data, but as active participants in the studies' planning, implementation, and critical review.

## NOTES

1. The CGIAR is an informal association of governments, international and regional organizations, and private foundations dedicated to improving agricultural technology, increasing food production, and raising the living standards of poor people in developing countries. Established in 1971, under the joint sponsorship of the World Bank, the United Nations Development Program (UNDP), and the UN's Food and Agriculture Organizations (FAO), the CGIAR System has expanded to include 13 international agricultural research centers which employ over 500 scientists and have an annual budget of approximately US $180 million. Programs of 10 commodity-oriented centers cover a range of crops, livestock and farming systems that provide roughly three-fourths of the developing world's total food supply. These centers are: CIAT (International Center for Tropical Agriculture) in Palmira, Colombia; CIMMYT (International Center for the Improvement of Maize and Wheat) in El Batan, Mexico; CIP (International Potato Center) in Lima, Peru; ICARDA (International Center for Agricultural Research in Dry Areas) in Lebanon and Syria; ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) in Hyderabad, India; IITA (International Institute of Tropical Agriculture) in Ibadan, Nigeria; ILCA (International Livestock Center for Africa) in Addis Ababa, Ethiopia; ILRAD (International Laboratory for Research on Animal Diseases) in Nairobi, Kenya; IRRI (International Rice Research Institute) in Los Banos, Philippines; and WARDA (West African Rice Development Association) in Monrovia, Liberia. The remaining three centers are concerned with problems of food policy, national agricultural research systems, and conservation and utilization of plant genetic resources. These centers are: IFPRI (International Food Policy Research Institute) in Washington, D.C., USA.; ISNAR (International Service for National Agricultural Research) in The Hague, Netherlands; and IBPGR (International Board for Plant Genetic Resources) in Rome, Italy. Success of the first two centers, CIMMYT and IRRI, precipitated what is often termed the "Green Revolution" with wheat and rice. For further information on the CGIAR see Ruttan (1982), CGIAR (1980), Pinstrup-Andersen (1982), and Arndt *et al.* (1977). CGIAR (1985) presents a summary of the impact study of international agricultural research centers.

2. The reader is referred to Pinstrup-Andersen (1982), Ruttan (1982), Arndt *et al.* (1977), Scobie (1979), and the works cited therein.

3. There are exceptions, of course, such as the recent article on a rice seed multiplication project in Sierra Leone by Kreul (1984).

4. On the subject of networking in international agricultural research see Plucknett and Smith (1984).

5. Based on 400 farm-level yield measurements in the Philippines, Potts (1983) concluded that actual potato yields in the Baguio area were roughly three times the official estimate.

6. The location specificity of technology adoption and response has been well documented in the case of irrigated versus rainfed rice. A series of "adoption studies" sponsored by CIMMYT in the 1970s also indicated that adoption and use of new maize and wheat varieties was strongly influenced by agro-ecological conditions. On this point see Barker (1971), Colmenares (1975), Demir (1976), Gafsi (1976), Gerhart (1975), Vyas (1975), and Winklemann (1976).

7. Ruthenberg (1980) is a valuable exception. However, the author presents very little information from Latin America.

8. The best material has been prepared in conjunction with IRRI's project on consequences of new rice technology. See, for example, IRRI (1978a, b).

9. Some of the international centers' experiences with and methods of on-farm research are discussed in IRRI (1977a, b; 1984); De Datta *et al.* (1978); Byerlee *et al.* (1980); Perrin *et al.* (1976); Byerlee *et al.* (1982); CIP (1982); Rhoades (1982a or b; 1984); Horton (1984; 1982); Zandstra *et al.* (1981). Shaner *et al.* (1982) outlines methods for on-farm research drawn from a number of sources.

10. Some of these aspects of on-farm experimentation are discussed in Davidson *et al.* (1967) and in Horton (1984).

11. See, for example, IRRI (1977a) and Potts (1983).

12. Some illustrative cases are noted in Section 4, *infra*, and in CIP (1984).

13. The most substantial body of work on demand projections is that of the FAO's Commodity Division. The basic methodology employed is detailed in FAO (1971) and the Working Papers cited therein.

14. Available statistics on recent changes in area, production, and yields of potatoes are presented in Horton and Fano (1984). Types of technological change and their significance are discussed in Horton and Sawyer (1985). Van der Zaag and Horton (1983), Monares (1984), Rhoades (1984), Horton (1984), and CIP (1984).

15. Economic analysis of different production constraints, including pests and diseases, was conducted at CIAT in the early 1970s. For a presentation of results for beans in Colombia see Pinstrup-Andersen (1976). CIP began an assessment of major potato pests and diseases in 1984.

16. The questionnaire and summary of results may be obtained from the author.

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