Impacts of Alternative Technical Progress on Global Food Production and Distribution

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Abstract: The evidence provided in this paper supports the view that the evaluation of the impacts of new technologies must be set in a general equilibrium framework if the results are to be valid. The paper also provides support for the need to bring into such impact analyses the effects on income distribution, welfare, and nutrition. Such a quantitative assessment of impacts could be a useful input into the allocation of international agricultural research resources.

Introduction

Ample evidence exists that returns to investments in agricultural research are high but funds for agricultural research are nonetheless limited and decisions on the allocation of scarce research funds to various tasks require appropriate criteria. This paper focusses on resource allocation within the international agricultural research system as influenced by considerations of the impact of agricultural research on global and national food production, distribution, and consumption.

Three international agricultural research centres concentrate their efforts on the most important grain crops; i.e., IRRI on rice, CIMMYT on wheat, and ICRISAT on millet and sorghum. In view of the expectations for the impacts of the work of those institutes, two issues arise:

- how to predict (in quantitative terms) the expected increases in yield and yield stability and the corresponding costs of research and extension; and
- what kind of impacts of expected increases in the productivity of major food crops should be taken into account and how to evaluate them.

Having found answers to those issues, policy conclusions can then be drawn regarding the overall amount of research and allocation to the various activities devoted to increasing yields of different crops.

This paper concentrates on the issue of assessing the impacts of alternative technical changes. Because of space limitations, it does not aim to make a full assessment of all aspects of such impacts but rather aims to indicate the complexity of such work. The data provided should also be considered as examples of changes rather than precise numbers.

Problem with Impact Assessments

A new yield-improving variety of a crop shifts the yield input relationship so that the new variety gives higher yields at economically relevant input levels. In fact, many of the high yielding varieties of different crops in India seem to be dominant in the sense that they give higher yields than traditional varieties at lower fertilizer levels (see Parikh, 1978).

Once such a variety is available, its impact will depend on the extent of its adoption and the level of inputs applied, which in turn depend mainly on how the profitability of the crop changes relative to its competing crops. The change in relative profitability depends on a number of factors, such as increase in yield, changes in related costs, and the policies that affect the prices farmers receive and consumers pay. Especially when the yield improvement is substantial and the technical progress applies to a large area, producer prices might be expected to go down, depending on demand and government policies. Hence, one might get biased results in assessing the impact of technical progress if those feedbacks are not taken into account.

In addition, if the country is large or if the variety improvements can be adopted by many countries and no barriers are in the way of price transmission, then changes in international trade volumes and prices will also affect the domestic prices. Thus, one should account for such feedbacks from the global market. An approach that simultaneously determines supply, demand, and market clearing prices at both national and international levels (i.e., a general equilibrium approach) is therefore advocated.

The system of linked national agricultural policy models—called the Basic Linked System (BLS)—of the Food and Agriculture Program (FAP) of the International Institute for Applied Systems Analysis (IIASA) is a tool that can be used for such impact assessments in a way that accounts for the various feedbacks described above. The objectives, approach, and scope of FAP are described in Parikh and Rabar (1981). The methodology and algorithms are given in Keyzer (1981). Fischer and Frohberg (1982) provide the technical description of many of the models of the system. The BLS links individual models of 20 countries or regions that have similar agricultural policies (which together represent more than 80 percent of the world in terms of population, area cultivated, and crop production) to 14 other aggregated models (to cover the remaining countries of the world) through trade, aid, and capital flows. The national models are of the general equilibrium type, and their parameters are mainly economically estimated. The model system clears the supply and demand of nine agricultural products and one nonagricultural product of all countries at equilibrium prices, both at the country and the world level. Certain country models (e.g., India) allow the effects of productivity increases to be traced back to resulting levels of production and to their effects on food distribution to different income groups. Here the BLS was used to assess the impacts of different scenarios of technical progress.

Alternative Scenarios of Technical Progress

To explore the impacts of effectively disseminated research that pushes up yield functions of wheat, rice, and coarse grains in the LDCs (except China) beyond the historical trends, three scenarios were generated and compared to the reference scenario where yield-improving technical progress in the LDCs (except China) follows the historical trend. Technical progress in the developed countries was assumed to follow past trends. The yield-improving technical progress that shifts the input response outward in a nonparallel fashion was postulated to be 25 percent above its historical trend for the selected crops; for all other crops, technical progress was kept on the historical trends. The additional technical progress of 25 percent was introduced gradually by 2.5 percent every year from 1981 to 1990 for all the developing countries where the crop is important.

Global Impacts on Production Prices

Table 1 shows the production changes in different countries and regions under the three scenarios. Although technical progress improves physical yield response to inputs by 25 percent (i.e.,

Table 1—Impacts of a 25 Percent Addition to Yield-Improving Technical Progress on Production in the Year 2000 (Changes from the Reference Run, in Percent)

	Wheat	Rice	Coarse Grains
Argentina	30	26	29
Australia	-10	-37	-12
Austria	-1	*	-2
Brazil	32	14	30
Canada	-14	*	-11
Egypt	55	-3	39
India	21	24	9
Indonesia	*	43	32
Japan	-3	-10	-4
Kenya	57	-9	43
Mexico	27	3	39
New Zealand	-4	*	-9
Nigeria	36	27	16
Pakistan	11	6	21
Thailand	*	3	45
Turkey	35	2	27
USA	-3	-9	-4
EC	-13	-8	-10

[*Not relevant for the country.]

gives 25 percent more yield for the same input level), yield changes vary substantially among the LDCs due to economic feedbacks. Moreover, technical progress in the LDCs affects the production structures of the developed countries as well, and those changes are also significant.

The direct impacts of technical progress on production come through higher yields at the same level of yield increasing inputs as with the old variety and through adjustments of input use. Although the marginal physical product is even higher at the old input level, the new optimal level of input use will very likely be at a higher marginal physical product than with the old variety because of a rise of the ratio of input to output prices. The output price change itself is a result of a production increase that is not fully compensated by a demand increase.

The price effects in the world market can be seen in Table 2. The postulated technical progress in developing countries has widely different effects on the world market prices of the three selected cereals, depending mainly on the LDC share of world production, the income and price elasticities of demand of the three commodities, and the world net export share of world production. The higher the share of production, the greater the price response; the higher world net export share of world production, the lower the price response. Thus, the least price response (7 percent relative to the reference run by 2000) is for wheat, which has a relatively low share (22 percent) of its production in LDCs (excluding China), with a medium share of world production traded. Coarse grains show an intermediate response and rice the highest, as 58 percent of it is grown in developing countries (excluding China) and only 3.2 percent of its world production was traded in 1980. At the same time, major differences exist in the degree of protection given to the different cereals in different countries. Thus, actual price effects on production depend on protection given to domestic prices and on their further impacts on the response to technical progress.

Impacts on Consumption

The investment in plant breeding leads (after a gestation period) to crop varieties that are more efficient in their input use, resulting in higher production (and, hence, more income) and in changed relative prices. Benefits from the investment occur over a long time span. To compare the different investment strategies, one should therefore convert the stream of benefits into a single number; e.g., into its present value by using a discount rate. In Table 3, the change of one indicator of such benefits is presented for various countries for the years 1990 and 2000. The change in equivalent income is used for this purpose since it measures welfare gains and losses. As Table 3 shows, the majority of countries shows welfare gains. That also holds largely true for developed countries. Most of them gain in welfare through reduced relative prices for agricultural products. Australia and Canada are exceptions, where income losses have a stronger impact than the changes in the price structure.

People in LDCs may also suffer welfare losses as the results for Brazil, Mexico, and Pakistan indicate. A negative impact of the changes in relative prices dominates the increases in income in those countries.

Equivalent income measures the overall welfare gain and losses but does not take into account other attributes; e.g., calorie intake or income distribution, which are important aspects (as shall be shown in the case of India).

The impacts on calorie intake under the various scenarios are somewhat difficult to compare because a 50 percent increase in yields of different crops adds different amounts of grains in a country. For example, if rice constitutes 50 percent of the production of cereals and coarse grains only 25 percent, then technical progress in rice would provide more additional food. One could construct the scenarios in a way that gives comparable technical progress in alternative crops. The comparability would be different for different purposes. For example, for nutritional impacts, one might consider technical progress that gives the same amount of additional grain production in alternative crops.

Yet the impacts on consumer groups with different incomes within a country are not easily predictable, as different grains constitute different proportions of diets of different income classes. The poor consume relatively more coarse grains in almost all LDCs.

The Indian model distinguishes different income classes (five rural and five urban). The classes are based on expenditure limits at base year prices, and the distribution of population in different expenditure classes shifts depending on the income level.

Table 2—Price Responses to Technical Progress in the World Market and Some Explanatory Factors Comparing Wheat, Rice, and Coarse Grains Scenarios with the Reference Run, in Percent

	Wheat	Rice	Coarse Grains
- - - Percentage change by the year 2000 in world market prices - - -*			
Wheat	-7.5	-0.5	-5.4
Rice	-0.2	-46.6	-0.9
Coarse grains	-1.5	-0.5	-8.1
- - - LDC share of world production† - - -			
1980	22	58	20
2000	33	70	23
- - - World net export share of world production† - - -			
1980	19.5	3.2	9.6
2000	22.3	8.6	14.5

[*Prices (which are normalized by using the nonagricultural price) are compared with those of the reference run. †Excluding China.]

Table 3—Impact of the Three Scenarios on Equivalent Income* in 1990 and 2000: Changes from the Reference Run, in Percent

	Wheat		Rice		Coarse Grains	
	1990	2000	1990	2000	1990	2000
Argentina	0.1	0.2	-0.0	0.0	0.3	0.4
Australia	-0.1	-0.1	-0.0	0.0	-0.1	-0.1
Austria	0.0	0.0	0.0	0.0	0.0	0.1
Brazil	0.1	-0.1	0.3	0.4	0.2	0.2
Canada	-0.1	-0.1	-0.0	-0.0	-0.1	-0.1
Egypt	0.0	0.1	-0.0	0.2	0.0	-0.1
India	0.4	1.4	1.1	3.3	0.3	0.2
Indonesia	0.3	-0.1	-0.6	4.9	0.5	0.5
Japan	0.1	0.0	0.3	0.4	0.1	0.2
Mexico	-0.1	0.1	0.1	0.1	-1.1	-3.5
Nigeria	0.1	0.0	0.2	0.3	0.3	0.1
Pakistan	0.4	0.2	-0.2	-0.1	-0.1	-0.3
Turkey	0.2	0.2	0.0	0.0	0.1	0.1
EC	0.0	0.0	0.0	0.0	0.0	0.0

[*Defined as income needed to purchase a consumption bundle at 1970 prices that would provide the same utility as provided by a current consumption bundle.]

Table 4 shows the per capita calorie intake in India. As can be expected, the highest average calorie intake is under technical progress in rice, as that commodity is by far the most important grain in India. The higher production increase in wheat than in coarse grains also shows up on the average calorie intake, which is (in the year 2000) higher in wheat than in coarse grains.

Table 4—Calorie Intake in India in the Year 2000 (kcal/person/day)

Scenario	Aggregate	Poorest Rural Class
Reference	2542	1103
Wheat	2608	1123
Rice	2643	1131
Coarse Grains	2560	1133

The average intake of the entire population cannot be extrapolated to the rural poorest income class. Differences in calorie intake per person are not as pronounced in that income class as for the total population. The increase in calorie intake is strongest for the poorest class in the coarse grain scenario, while it shows the least increase for the average population.

However, since the number of people in the rural poorest class is different, a simple comparison of average per capita calorie intake is not meaningful. Yet in the rice scenario, the calorie intake distribution across different classes is less uneven than under the other two scenarios. Thus, the distributive impact of technical progress in different crops is different.

Concluding Comments

Technical progress in one country or one crop affects the production of others. Moreover, the feedback from income, demand, and prices is important in determining the actual increases in production that might result. The distributive impacts can also be different.

For determining an international crop research strategy, such assessments of the benefits of research results can be valuable. Of course, one also needs to obtain an idea of the costs and likelihood of technical progress in alternative crops and of the values attached to individual development objectives in a multiobjective policy setting.

Note

[1]International Institute for Applied Systems Analysis. The authors wish to thank M. van Oppen, who brought the topic to our attention, for his stimulating suggestions on this paper.

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