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CONSTRAINTS TO THE DEVELOPMENT AND USE OF IMPROVED TECHNOLOGY

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Introduction

This topic is both easy and difficult to address. It is easy to come up with a list of constraints that is sufficient to explain why productivity has not increased more. However, it is difficult to say something general about constraints that is not already well known. It is also difficult to identify promising solutions.

I hope to accomplish the following in my presentation:

- briefly present a general framework for identifying constraints;
- focus on specific constraints or issues that merit more attention;
- present key lessons that have emerged from the studies of the rate of return (ROR) to agricultural research investment conducted by Michigan State University (MSU) under the AID-funded Food Security in Africa and Food Security II Cooperative Agreements; and
- suggest some general conclusions.

The studies that I will be describing were carried out by a large group of MSU faculty, graduate students, and collaborators from other national and international organizations. Their collective efforts are acknowledged here. The studies are described in more detail, along with other studies of agricultural research impact, in Oehmke and Crawford (1993).

Conceptual Framework

Research impact occurs when improved varieties or production practices are adopted by farmers, resulting in lower costs and/or increased output. To identify factors that might block this from happening, it is helpful to look at the causal chain of events involved in technology development, transfer, and adoption. This chain of events can be summarized as follows:

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1. Needs identification and research problem definition.
2. Investment in agricultural research.
3. Generation of an improved technology (variety, input package, agronomic practices, etc.) by the research program.
4. Transfer of the improved technology to farmers.
5. Adoption and effective use of the improved technology by farmers.

Constraints may arise at each step of this process:

1. The research problem may be inappropriately defined.
2. The research investment may be inadequate (country too poor).
3. The research team may fail to produce anything.
4. A new technology may be produced, but may not be appropriate for farmer circumstances.
5. Organizations in charge of transferring technology to farmers, or providing support services, may not do their job effectively.
6. Farmers may refuse to adopt the technology being offered.
7. Or farmers may adopt the technology only partially, or manage it incorrectly, so that potential productivity gains are not realized.
8. Lastly, productivity gains may occur, but no market exist for the increased output.

Whether this process works well, or whether constraints arise, is affected by:

1. The country's basic resource endowment (agroclimatic, human). The harsher the physical environment and the poorer the resources, the harder it is to achieve a given improvement in technology.
2. The political and economic environment, including institutions and government policy.
3. Unfortunately, any one of these constraints can be severe enough to stop the technology development and transfer (TDT) train from reaching the end of the line.
4. This underlines the importance of country- and region-specific diagnosis of constraints, and identification of solutions.

I do not want to say more about this in general. Each of these constraints is a large research topic in itself, and I am sure that other workshop participants could discuss them more knowledgeably than I.

Specific Issues to Emphasize Regarding Constraints

Taking a systems perspective to the problem is critical. One important system is the commodity sector, which has a vertical dimension. The critical constraints may pertain to marketing, processing, or final demand, rather than to farm-level production. Example: maize in Mali (high cost of processing maize meal into a form acceptable to consumers limits the potential for expanding the role of maize beyond that of "hungry season" crop consumed green).

Another important system is the farm household, which has a horizontal dimension. The farm family is likely to attach a value to activities other than the farm production enterprise that is the focus of TDT investment. This would include other crop and livestock production, agricultural processing and trading, and other nonagricultural income-earning endeavors. As my colleague Tom Reardon has shown, this diversification of income-earning activities is a response to risk that helps stabilize income levels.

Because the farm household system counts more than any individual enterprise, investing in a particular enterprise (to take advantage of improved technology) may be unattractive to the farmer:

1. The gains from the investment in improved technology may have unacceptably high opportunity costs in terms of reduced income from other household activities (a result of competition for the household's scarce labor and capital resources).
2. Other uses of the farmer's capital, e.g., for nonfarm activities, may have higher perceived returns. Indeed, many rural households may not be primarily farm oriented.
3. A focus on single commodities is therefore likely to fail.

Farmer willingness to invest in improved technology is limited by (a) imperfect markets for inputs, credit, and outputs; (b) price and yield risk; and (c) imperfect information.

Demand constraints are often important. On the product side, consumer preferences must be considered. Example: soybeans in Uganda are used for both animal feed and human consumption. Improved varieties have a dark colored bean, which is fine for animal feed but not for human consumption, because people prefer a light-colored grain.

On the input side, effective demand may be limited due to cash constraints, or high perceived risk. Example: fertilizer demand in Senegal (Kelly, 1988).

Macro-level policies and institutions, including property rights and other "rules of the game," are important in creating a climate and incentives that encourage successful TDT.

Example: Maize in Mali was rapidly expanded thanks to attractive guaranteed prices, and an integrated technology delivery and marketing system established by the cotton parastatal. The same points apply to transport, marketing, and communications infrastructure.

More refined analysis of constraints is needed to move beyond a simple view of technology development and adoption to take account of sustainability and second-generation technology issues. The technical and financial/economic dimensions of sustainability are both important.

Technologies that increase productivity over the long run are more difficult to develop, transfer, and effectively implement than those which achieve short-run productivity gains. In other words, constraints in addition to those itemized above become important if the goal is sustainable TDT. Some of these are micro-level and technical (maintenance of soil quality); some are macro-level and institutional (incentives for collective action to conserve common resources).

One question that is relevant here is whether there are any significant differences between productivity investments (PI) and sustainability or conservation investments (CI) that have implications for constraints and how to solve them. This topic is discussed in Reardon and Vosti (1992). In this paper, the authors emphasize the following points:

1. Sustainability may be defined in at least three ways:
   - conservation of the resource base and long-term resource productivity;
   - maintenance of income levels or growth rates;
   - sustainable livelihoods--consumption.
2. There is a continuum of types of investments, ranging from productivity-oriented investments (PI) to conservation-oriented investments (CI). Some investments may increase productivity but harm the resource base. Some may increase productivity but help the resource base (termed "overlap technologies" by Reardon and Vosti, e.g., bunds plus fertilizer). Some may improve the resource base but harm productivity.
3. Similarities between PI and CI include:
   - both require household expenditures on inputs;
   - both require inputs of goods and services supplied by private and public sectors.
4. Differences between PI and CI include:
   - CI are perceived as less tangible, or more risky, or more long-term than PI;
   - externalities caused by CI may discourage adoption;

- CI may be more lumpy than PI, therefore more difficult to finance;
- labor constraints may affect CI more than PI;
- less credit may be available for CI than for PI;
- equipment and extension advice may be less available for CI than for PI.

As a result of these differences, promoting CI is likely to require different policy and program interventions than promoting PI.

Financial profitability is important to all commodity sector participants, including farmers, processors, and traders. The difficulties of maintaining quality and profitability in seed multiplication and distribution were evident in most of the countries studied (especially Niger and Uganda), with some successes in Zambia and Mali. The need for processing firms to achieve a high enough throughput to reduce unit costs to a profitable level was particularly evident for oilseeds in Uganda.

At the macro level, economic profitability is important in the long run. Government price supports and marketing and input subsidies impose a budgetary cost that is hard to sustain. (This is illustrated by the Zambia example discussed later.) Alternative solutions for reducing such budgetary costs include:

1. Aligning TDT more closely to current or probable future comparative advantage.
2. Institutional and policy reform to improve market performance and reduce transactions costs so that fewer budgetary subsidies are needed to create incentives.

Second-generation technology issues call for a more fine-tuned analysis of constraints and possible solutions. Following Byerlee's 1992 paper, one can subdivide the productivity improvement process into several stages:

1. Pre-Green Revolution: expansion of area cultivated.
2. Green Revolution: high-yielding, input-responsive varieties greatly increase land productivity.
3. First post-Green Revolution phase: further intensification of chemical input use as a substitute for increasingly scarce land. The result is greater allocative efficiency.
4. Second post-Green Revolution phase: use of better information and management skills to boost productivity at high input levels. The result is greater technical efficiency.

What the critical constraints are, and how best to overcome them, depends on what stage of TDT is involved. Tailoring and sequencing solutions to suit specific environments is critical.

1. Initially, technology can be imported and the local research system may play a limited role.
2. To maintain Green Revolution gains, however, requires establishing a strong breeding program to continually renew the disease and pest resistance of the high-yielding varieties (HYVs). The basic physical infrastructure and support services must be put in place, largely with public investment.
3. The first post-Green Revolution phase requires strong crop and resource management research programs, and policies that encourage greater private sector participation in input delivery.
4. The second post-Green Revolution phase requires farmer education, training, and improved information dissemination systems. As information and management skills allow inputs to be used more efficiently, input subsidies may decline.
5. Post-Green Revolution phases often also require policy interventions to reduce market imperfections and stabilize incomes.
6. Achieving sustainable productivity gains requires monitoring of resource quality, and adaptive research to identify sustainable practices appropriate to local circumstances.

Lessons from the MSU ROR Studies

Earlier in the workshop, Jim Oehmke discussed the studies of returns to agricultural research that MSU carried out in seven countries of Africa during 1991 and 1992. I would like to highlight some lessons from five of the studies, namely Cameroon, Mali, Niger, Uganda, and Zambia.

Let me make three comments about the nature of these studies. Each included the following elements:

1. A calculation of the rate of return to agricultural research investment, including benefits to date and (usually) a projection over the next five to ten years. A second, more explicitly ex ante, study was conducted in Uganda.
2. Inclusion of the costs of activities other than research, such as seed multiplication and distribution, extension, and marketing, that contributed to the benefits being measured. In some cases, e.g., Zambia, the costs of incentive policies (price supports, marketing subsidies) were also included. (Since these activities are

complementary to the investment in agricultural research, it is difficult if not impossible to isolate the impact of research alone.)

3. An emphasis on asking not only "What was the rate of return?" but also "Why did that result occur?" What factors had a positive or negative influence on returns? In answering these questions, policy and institutional factors received special attention.

Major findings from the MSU studies are summarized below by country.

Uganda

1. The subsector or commodity sector approach used in the study, by not focusing exclusively on the producer level, helped to reveal constraints that might otherwise be missed, such as:
   - the importance of regional export demand for maize;
   - the limited domestic demand for soybeans for animal feed constrained the expansion of edible oil processing;
   - the mismatch between available HYVs of soybeans (dark color) and consumer preferences (light color);
   - expanded use of rhizobium inoculation for soybeans was constrained by poor quality control in production and distribution, and a weak extension system;
   - research is needed to increase sunflower yields in order to break the vicious circle of low production, low supply for processing, high processing costs, low processing profitability, and hence low prices offered to farmers by processors;
   - production and quality problems severely constrain hybrid sunflower seed multiplication and distribution.
2. Macro constraints include:
   - political instability;
   - the recent fall in international coffee prices reduced government revenues, which limited the government's ability to finance research and agricultural support services;
   - government policies have created disincentives to private sector input supply.

Niger

1. Low rates of return were explained by constraints on development, transfer, and adoption of improved technology.
   a. Technology development faced the serious challenge of:
      - harsh, variable climate, with scarce water and poor soils;
      - research priorities that were science-driven, rather than demand-driven, resulting in inappropriate high-input technology for monocrop systems.
   b. Technology transfer was constrained by:
      - a donor-supported seed multiplication and distribution system that was too costly to be sustainable;
      - an extension system weakened by frequent reorganizations, shifts in extension philosophy, and lack of training and operating funds.
   c. Adoption was constrained by:
      - low market prices for the output;
      - deficient infrastructure, leading to high transport costs;
      - unavailable seeds and inputs;
      - capital constraints;
      - weak extension system.
2. The study raises issues about research priorities, and highlights:
   a. The need for demand-driven research.
   b. The need for reflection on the appropriate balance between national-level varietal development research and crop management research, and between crop research and livestock research (given Niger's arid environment and large cattle population).

Mali

The high rate of return to maize research was explained by:

1. The low cost of the research included in the analysis. The development of improved maize varieties under French-supported programs was based on inexpensive screening. It also occurred prior to the 1969 launching of the national maize research program analyzed in the study. (Including research costs beginning in 1962 reduced the IRR from 135% to 54%.)

2. The high economic value of maize, as an import substitute.
3. The rapid rate of adoption, which was spurred by investments in physical capital, support services, and incentive policies (attractive, guaranteed producer price).
4. The agency promoting maize (CMDT) used the same type of integrated technology delivery and output marketing system that it had applied successfully for cotton.
5. Subsequent liberalization of the maize sector placed more responsibility for these functions in the hands of private sector actors. The attendant decentralization greatly increased the challenge of coordinating the necessary input supply and marketing functions.

Zambia

Zambia constitutes an example of successful investment in TDT, where the spread of the new technology was pushed beyond the limits of comparative advantage by a package of unsustainable government policy incentives. The investment in agricultural research led to the release of 10 improved hybrids and open-pollinated varieties in the 1980s. By 1991, more than 60% of total maize area was planted to these varieties. Between 1983/84 and 1988/89, maize area rose by 40% and output more than doubled, with most of the increase coming from smallholder areas.

Factors that contributed to these changes included:

1. Development of varieties adapted to small farmer needs, with superior yields, shorter growing periods, and better drought tolerance and disease resistance.
2. An effective semi-commercial seed company (ZAMSEED), with distribution through farmer cooperatives.
3. Credit and extension programs that reached at least 50% of small farmers
4. Widespread (90%) use of fertilizer.

The costs of the government's maize support program, in terms of producer price supports, credit, and subsidies for fertilizer, transport, and milling, proved insupportable. The uneconomic nature of these policies is indicated by the negative ROR that resulted when the costs of marketing subsidies were included. Elimination of these subsidies led to a substantial decline in maize area and output, down to only 3% and 50% above the 1983 levels, respectively.

Lessons regarding institutional factors include:

1. Private-sector multiplication and distribution of improved seed can be successful.

2. Coordinated support policies, including inputs, information, and marketing services, can boost adoption significantly.
3. Individual researchers or small teams can develop significantly improved varieties, providing there is continuity of personnel and financial support.
4. By the same token, a successful research program based on one or a few individuals can be decimated overnight if those individuals leave the research organization.

Cameroon

This study examined the impact of research and extension programs for cowpea and sorghum. Key features and implications are:

1. For both crops, the improved varieties did not result from an in-country breeding program, but were identified by screening cultivars provided by IITA.
2. The cowpea program was more successful because the improved cowpea variety met the farmers' needs for an early maturing food crop, and alternative to cotton as a cash crop. By contrast, the sorghum variety studied was not superior to existing varieties except in its drought resistance, which is a feature that provides benefits on average in only one out of three years when rainfall is inadequate.
3. Major lessons that can be drawn from the Cameroon study include:
   a. The choice of constraint to address through research can have as much effect on the ROR as the actual research that follows. I.e., even though cowpea is a minor crop, the research paid off more because it addressed an important need.
   b. Institutional linkages were critical to the success of the programs:
      - the donor project facilitated links between research, extension, and seed supply;
      - the donor project facilitated links between the national agricultural research system (NARS) and IITA;
      - the system allowed for considerable feedback from farmers to researchers, through the on-farm trials and the extension service. Among other things, this led to a switch in the cowpea research program's emphasis from yield to storage pest resistance.
   c. The choice of the cotton parastatal, SODECOTON, as the implementing agency, had both advantages and disadvantages. It ensured good integration

between extension and input distribution, but it meant that the program reached only the 40% of farmers who were cotton growers.

Conclusions

1. It is important to take a country- or region-specific approach to diagnosing constraints and identifying solutions.
2. Technology development needs to be demand-driven. Cowpeas in Cameroon and maize in Zambia are positive examples. Millet and cowpeas in Niger and soybeans in Uganda illustrate the limited success of unwanted new technologies.
3. A commodity sector perspective is vital for identification of key constraints, and hence for definition of top priority research problems. Marketing and processing constraints may be more critical than production constraints, as the Mali maize and Uganda soybean and sunflower cases illustrate.
4. Seed supply is critical. Cameroon, Mali, and Zambia exemplify this point. Niger and Uganda exemplify the constraints posed by poor seed supply.
5. More broadly, coordination of input supply and marketing functions is critical. Mali maize and Cameroon cowpea are cases where parastatal development organizations filled these roles. Complementary policy incentives, as in Mali and Zambia, also contribute to success.
6. The challenge is not only how to overcome constraints that may arise at various stages of the TDT process, but to do so in a way that is sustainable in technical and economic terms. How to make pro-sustainability investments pay off?

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