TECHNOLOGY FRONTIERS: THE SUBSECTOR APPROACH TO ANALYSIS OF AGRICULTURAL TECHNOLOGY IMPACTS

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SUMMARY

This report summarizes the findings of a project to investigate the use of subsector or commodity-sector analysis in informing decisions about investment in African agricultural research. The specific objectives of the project are: 1) To provide guidelines for the use of technology impact assessments and commodity sector analyses in determining research priorities; 2) To synthesize the implications of the Mali, Uganda and Zambia impact assessment studies, as examples of the commodity sector approach, with respect to setting agricultural research priorities; 3)To identify improvements in the guidelines needed to increase its value as a tool for setting agricultural research priorities; and 4) To communicate the findings of the above synthesis to AID personnel and members of the international research community. This report presents the results of the investigations relevant to the first three objectives, and contributes to the fourth.

The project is a 'desk-study' activity that mixes methodological development with the case study approaches. Part of the project draws out the lessons from three African case studies of research impact; each of these studies also contributes to our understanding of how the commodity-sector approach can be used to learn more about past or potential future impacts. The conceptual studies help to define the context in which the commodity-sector approach best operates as it applies to research, by defining and modeling the relationships from technical change at a particular point in an agricultural commodity sector to agricultural growth to broad-based economic growth.

The most significant methodological findings are;

- The major contribution of the commodity-sector approach in *ex-post* assessment is the recognition of the roles played by input and output markets.
- The major contribution of the commodity-sector approach in *ex-ante* analysis is in the determination of leverage points in the commodity sector.
- The commodity-sector approach is compatible with neo-classical performance measures, and applied commodity-sector analysis would benefit from greater reliance on such measures.

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- A commodity-sector performance measure relevant to assessing the impact of technical change in the sector on aggregate economic growth is the contribution of the technical change to the growth in gross domestic product originating in the commodity sector.
- Available measures quantifying the impact of technical change in a commodity sector on aggregate growth through linkages or multipliers are generally *ad hoc* and not closely tied to a relevant growth theory.
- The derivation of enterprise budgets for the various stages of the commodity sector, including how technical innovation has or might affect these budgets, is perhaps the most critical step in executing a technology impact assessment through commodity-sector analysis.
- Analysis of enterprise budgets may need to be complemented by market or consumer-demand studies.

In addition to the methodological findings, some interesting development results arise:

- The interactions among technical innovations and markets strongly affects the magnitude and distribution of impact.
- Output markets appear to be more critical than input markets in determining the magnitude of impact on agricultural transformation.
- The existence of a well-functioning input market is insufficient to generate demand for the output. The existence of a well-functioning output market may encourage development of an input market or other supply mechanisms.
- Farmers, particularly smallholders, who use markets tend to rely on local markets.

The conclusion is that the commodity-sector approach can provide significant contributions to the analysis of past and potential future research impacts, and thereby contribute to strategic planning for technology development and transfer.

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1. Introduction

Despite increasing evidence that investments in African agricultural research have generated positive impacts and high rates of return over the past two decades (Oehmke and Crawford), African agriculture has shown little evidence of transformation into an efficient and productive sector capable of sustainably feeding the African population. A critical question for the future of African agriculture is how best to use investments in research and development to maximum effectiveness in stimulating agricultural transformation. The Michigan State University activity is designed to provide information on this question, and on the use of the commodity-sector approach to inform the research-resource-allocation decision.

The specific objectives of the project are

1. To provide guidelines for the use of technology impact assessments and commodity sector analyses in determining research priorities.

2. To synthesize the implications of the Mali, Uganda and Zambia impact assessment studies, as examples of the commodity sector approach, with respect to setting agricultural research priorities.

3. To identify improvements in the guidelines needed to increase its value as a tool for setting agricultural research priorities.

4. To communicate the findings of the above synthesis to AID personnel and members of the international research community.

This report synthesizes the activities and findings pertaining to the first three objectives. While most of the findings are derived directly from the project activities, in some instances outside information is brought in to inform a particular issue.

The project activities included refinement of three case studies, initiated under the impact assessment activity, to draw lessons relevant to the use of commodity-sector analysis for research program design and priority setting. In two of the case studies, Mali and Uganda, the commodity-sector approach was explicitly built into the impact assessments (Boughton, Laker-Ojok). In Zambia the impact assessment was complemented by an institutional analysis (Howard), but since the important institutions include government marketing structures, this case study has much in common with and important lessons for commodity-sector approaches. The country-level perspective of the case studies is complemented by three conceptual studies. The first of these presents a model for analyzing the impacts of technical change in a commodity-

sector perspective (Oehmke, 1995a), and is largely directed towards objectives 1 and 3. The second conceptual paper (Oehmke, 1995b), developed concurrently with the first, takes a sectoral approach to define performance targets for agriculture that are consistent with social goals and can be analyzed using the approach developed in the first paper. The third study (Dinopoulos) links agricultural and broad-based economic growth, emphasizing the contribution of research and development in the agricultural and non-agricultural sectors to aggregate growth. The project activities thus span the range from analysis of specific, commodity-based research activities to broader issues of agricultural performance and economic growth.

2. The Commodity-Sector Approach

2.1 Background and Concepts

Early discussions of the commodity-sector or subsector approach to economic analysis revolve around taking a broader or systems perspective to the analysis of farm problems. For example, Shaffer argues that

> The uniqueness of subsector studies is not in the methodology or approach but in the scope and comprehensiveness of the research. The area of research is simply defined to included both the vertical and horizontal relationships in a significant part of the food and fiber sector (Shaffer, 1973, p. 333)."

The critical argument is that Shaffer feels that traditional studies are too narrowly defined to address the questions of interest (Shaffer, 1980), and that a more comprehensive view is needed. He states that "closely tied to my perception of subsector studies is what I would call a systems orientation ...analysis of economic activity in the context of a broader system (Shaffer, 1973, p. 334)." Key components of Shaffer's system include physical transformation of products, and dimensions of institutional, organizational and human behavior.

Expositions of the subsector approach sometimes use a matrix of activities within the food and fiber sector (?). Note that the boxes represent the people and institutions or actions taken by people or institutions, not goods, services or physical transformations. This depiction reflects the emphasis that practitioners of the subsector approach place on links among farmers, processors and producers of intermediate goods and services, and consumers.

Applications of the subsector approach proceeded primarily in two directions: those studies focussing on horizontal slices of the matrix, and those focussing on vertical slices. Consumer preference studies, market analysis, retailing studies and other analyses considering multiple commodities can be thought of as subsector analyses, by Shaffer's 1973 definition. In agriculture, the most heralded approach to examining a horizontal slice of the food and fiber sector is farming systems research, although that appears to have had quite different roots. In current

nomenclature, farming systems and other research on horizontal slices of the farm and fiber sector are considered to be unique and quite distinct from the subsector approach.

The second type of application emphasizes the examination of vertical slices of the food and fiber sector. This was a primary consideration in early subsector work, departing from the farm as the more traditional focus of agricultural economics research. Indeed, Shaffer defined the commodity sector as "the vertical set of activities in the production and distribution of a closely related set of commodities (Shaffer, 1969, p. 3, quoted by Ninnin, p. 2)." Over time, the terms subsector and commodity-sector analysis have grown to be associated with analyses of coordination in a vertical slice of the farm and fiber sector. Thus, there are strong links between the Canadian production-to-consumption sequence approach and the French filiere (Navarro and Schmid.). Throughout the current paper the term 'commodity sector' shall be used to denote these concepts.

2.2 Defining the Commodity Sector

Despite the current emphasis of commodity-sector studies on vertical slices of the food and fiber sector, the definition of a commodity sector remains somewhat ambiguous. Neither the extent nor the starting point of the commodity sector is defined *a priori* (although the farm is often used as a starting point), so that two different commodity-sector studies may be looking at very different segments of the same vertical slice.

Even the definition of 'commodity' remains somewhat ambiguous: is it based on farm-level definitions of commodity, such as wheat, which may imply looking at a wide range of intermediate and final goods such as feed, fodder, bread and other flour-based products, pilafs or other meal or grain-based products, etc.; or on consumer-level definitions, such as pastry, which may use as inputs the products from wheat, dairy, poultry, fruit, and other types of farming activities. The conceptual answer appears to be 'it depends on the question being asked'; Boughton (p. 309) and Shaffer argue that this flexibility is one of the strengths of the approach. However, most agricultural studies define the commodity sector in terms of the raw agricultural commodity (wheat, maize, etc.).

The emphasis on the sector defined by the agricultural commodity and on-farm production as the initial point of investigation into the commodity sector (although not necessarily the origin of the sector) is maintained throughout the case and conceptual studies investigated in this project.

2.3 Developing the Commodity Sector Perspective

Because the commodity sector was originally conceived of as a perspective and not a particular method, much of the work on developing the commodity sector approach has focussed on distinguishing this approach from others, most notably from 'neo-classical economics'. For

example, Ninnin argues against use of what is described as a stereotyped, standard neo-classical perspective because "it draws recommendations based on counterfactual assumptions (p. 7)."

It is unfortunate that much effort has been spent on comparing the commodity-sector perspective to neoclassical economics, for it has detracted from each perspective. Critiques of neo-classical economics are often based on the simplest partial-equilibrium models presented in Introductory Economics classes. For example, some apologies for a commodity-sector paradigm regard anything less than complete information as a foreign to neo-classical economics, when Grossman and Stiglitz show how information and the acquisition of a limited amount of information is in fact the outcome of rational behavior in a market economy, and when the entire principal-agent literature is an investigation into one type of vertical coordination with asymmetric information. Similarly, the neo-classical model is characterized as neglecting important social issues by relying on competitive markets as the standard against which other market structures are to be measured. In fact, there is a considerable overlap in perspective. This is perhaps best exemplified by Sonnenschein's description of the business of economics, which applies equally well to the systemic perspective defined by Shaffer as to the classical and neo-classical paradigms on which it is based:

> From its infancy in the eighteenth century, the framework of economic analysis has had three major ingredients. First, it takes as axiomatic that economic agents act on their own behalf, with or without sympathy for others. ... Second, the framework takes *social* equilibrium to be the concern of economic analysis. ... Finally, the framework of economic analysis takes the goals of individual economic agents to be in conflict; it views it as the business of economics and social science to determine the extent to which this conflict does or does not result in the efficient use of resources, promote the social good, and so on (Sonnenschein, p.4, italics in original)."

Alston, Norton and Pardey make a similar statement with respect to criticisms of the neoclassical approach to assessment of impact assessment, with the reliance on economic surplus as a measure and economic efficiency as the concept to be measured:

> Criticisms related to transactions costs and incomplete risk markets (which are part of a broader range of criticisms of economic surplus measures that center on 'market failures' or 'second-best' problems) pertain more to the assumptions conventionally used in economic surplus measurement rather than the neoclassical paradigm, which can, of course, accommodate imperfect information, transaction costs, and so on. The real issues in deciding just how to modify the empirical analysis to accommodate such problems are empirical ones (p. 53, parenthetical remark in original).

Shaffer (1996) regards the commodity-sector approach as falling within the neoclassical paradigm, the discussion being about what to take into account and what to omit. It is the finding of this project that a commodity-sector perspective can help to illuminate the choice of empirical measure and interpretation of such measures.

2.4 Application to the Evaluation of Research Impacts

Since there is little divergence in the perspective, the question becomes one of how does the commodity-sector approach assist with the design of more efficient research programs?

The commodity-sector approach can contribute to research program design in two ways. First, it can define leverage points in the commodity sector. Leverage points may be bottlenecks, the alleviation of which will allow the entire sector to perform better, or other opportunities for technical (or policy or institutional) innovation to enhance the commodity sector's contribution to sustainable growth or other social goals. By determining where these leverage points are, the commodity-sector approach contributes to improved research planning. Often these leverage points occur beyond the farm gate:

> Within the farming system--where most of the world's poor live--there exist few opportunities to improve household welfare. Most farms in (developing countries) are at least semi-commercial, and linkages further down the commodity chain often provide the greatest potential for change. Often the binding constraints to increased farm production are more related to ineffective or inefficient marketing activities than they are to farm technologies (Sellen, Howard and Goddard, p. 1).

Consequently, use of the commodity-sector perspective can identify where technical (or other) innovation can make the greatest contribution to improvement in the broad agricultural sector, and where the impact of technical innovation may be thwarted by other constraints..

The second use of the commodity-sector approach in research design is to can to help examine the distributional consequences and impacts of actual or proposed research agendas and technical innovations. Alston, Norton and Pardey find that

> This analysis of the "functional distribution" of research benefits has been extended in a number of recent studies, ... [which] have shown that the total research benefit and the functional distribution of research benefits among factors employed at different stages of production (or among nations when semi-processed products are traded) depend on several things in addition to those represented in the basic model unless the factors are used in fixed proportions. These additional aspects include (a) the stage of the production process to which the research applies, (b) the nature of the research-induced technical change, and © more detailed technological and market parameters. These results have implications for the allocation of private or public research resources within a country between programs applying at different stages in multistage production processes (p. 71, parenthetical remark in original).

The commodity-sector approach, with its emphasis on vertical linkages, is well suited to address these issues regarding distributional consequence of research and the allocation of public-sector resources to research and development activities.

2.5 Implementation

2.5.1 Measuring Sectoral Performance

Since the commodity-sector paradigm does not embrace any particular method of analysis, measures of sectoral performance often vary. Perhaps because of the alleged conflict between the commodity-sector and neo-classical perspectives, performance measures such as the growth rate in gross domestic product originating in the commodity sector are rarely used. Domestic resource costs, price volatility, throughput, and many other measures are used to determine if the sector is performing adequately, often with only tenuous links to the development objectives or vision set for the sector.

For example, thin markets--those with low throughput--are often characterized as inefficient due to lack of competition; 'thick' markets are believed not to suffer from this particular problem. Yet the market for U.S. Treasury bonds provides a counter example. Despite being one of the largest markets in the world and subject to a plethora of government regulations, this market has apparently been subject to manipulation by U.S. investment banks or their employees. In addition, in Africa it is not surprising to find that private markets, which often are thin, are efficient (in a static sense) but costly. In the research analysis context, market size does appear to be related to the magnitude of research impact, but impact measures and investment rules based on market size (such as the congruence rule) are often poor substitutes for the economic surplus approach (Alston, Norton and Pardey).

As another example, Martin finds it "tempting to define performance [in American grain-marketing systems] as the level of prices received by producers (p. 889)", citing several empirical studies which do so, but finding that this is insufficient. He concludes with a list of 42 performance measures that are important in characterizing sectoral performance, yet this list includes neither the value of final goods and services produced in the sector (although he does talk about a "trend in output or value added per unit of labor/capital), nor anything that could be construed as a measure of the social gains from the production, trade and consumption of the commodity. Similarly, citing Marion and Mueller, Shaffer's view of performance is one "concerned with allocative and technical efficiency, progressiveness, product characteristics, and equity (1980, p. 310)."

The issue is further confused because the commodity-sector paradigm is most frequently used in policy analysis. Some measures of sectoral performance, such as the correlation between domestic and world prices, may represent adequately the magnitude of policy or other distortions

in particular markets or commodity sectors, but are not always appropriate measures of performance for studies focussed on research impact or design.

One interesting development is the emergence of enterprise and commodity-sector budgets as a commonly-used basis for quantification of sectoral performance. In a methodological discussion of the commodity-sector approach and application to competitiveness in cocoa, Freud and Freud place primary importance on the cost structure within the commodity sector:

> A range of structural factors determine the basis for a country's competitiveness in the production and sale of a primary commodity such as cocoa ... It is the combination of these factors which determines the structure of costs of the subsector, ...a system covering the totality of the production process, from the upstream activities of input and credit supply to the downstream activities of processing and sale on international markets (p. 2).

Freud and Freud use what is essentially an enterprise-budget approach to investigate this cost structure:

> The basic building blocks of the analysis are detailed operating accounts for representative agents at different stages of the commodity system, including production, processing, and the various stages of commercialization, from the farm-gate up to the cost-insurance-freight point. These primary accounts provide information on the cost of purchased inputs and services (the intermediate consumption category), and the share of value added going to direct wages, interest payments, taxes (or subsidies), depreciation of investments, and profits (pp. 4-5, parenthetical remarks in original).

Enterprise budgets, necessary for the construction of measures such as domestic-resource-cost ratios (e.g. Freud and Freud, or Laker-Ojok), can be used to provide information on a number of the measures proposed by Martin, and Oehmke (1995a) demonstrates their use in determining how technical innovation contributes to economic growth in the commodity sector. Each of the three case studies make at least some use of enterprise budgets in constructing performance measures.

One approach to the use of enterprise budgets in a vertically linked fashion is the policy analysis matrix (PAM). "The PAM approach is designed to address three prinicipal issuess--the impact of policy on competitiveness, the influence of investment policy on economic efficiency and comparative advantage, and the impact of agricultural resarch policy on new technologies (Sellen, Howard and Goddard, p. 30)." The matrix itself usually contains abridged enterprise budgets, e.g. budgets that may list only the gross category variable costs as opposed to line items. However, the underlying principles are the same as with the more extensive budgets, and with care, similar use could be made of the PAM. While assessment of technological impacts is not one of the three principal issues, the approach is easily extended to cover impact assessment. A thorough development of the PAM is provided in Monke and Pearson.

The Mali and Uganda case studies rely on traditional, commodity-sector performance measures, such as market thinness (Mali) and volatility of marketing margins (Uganda), although Laker-Ojok makes use of domestic-resource-cost ratios and the PAM structure to bring in other measures of performance.. Because the Zambia study is more focussed on the market institutions rather than markets, Howard uses rate-of-return measures to quantifying the impact of the market institutions on economic performance, although the discussions also contain information that may be relevant to more traditional commodity-sector performance.

One of the conceptual papers directly address the question of measures of performance at the level of the commodity sector (Oehmke, 1995a), and two address it at the level of the agricultural sector (Oehmke, 1995b; Dinopoulos).

2.5.2 Conducting Commodity-Sector Studies

There is no paradigm for how to conduct a commodity-sector study. Reliance on key informants, at least in short-term studies and early stages of long-term studies, seems to be common practice. One notable development in the implementation of commodity-sector studies is the emergence of the rapid appraisal technique as providing a first cut at identifying participants, problems and opportunities in the commodity sector (Holtzman et al., Bernsten and Staatz). The output from this approach is usually a diagram of the major actors in the subsector and links among them, along with a description of the actors and their actions. The rapid appraisal is used to determine if and where more in-depth analysis is needed in order to resolve the outstanding issue. Follow-up activities depend on the issues, commodity, and nature of the commodity sector.

In comparing a number of commodity-sector studies, Ninnin lays out at least one set of activities that seem to make up a reasonably thorough study:

> 1) A market appraisal to assess the demand side; 2) A technical evaluation, which shows the prospects for technological changes and concerns in many different disciplines (crop breeding, pathology, agronomy, and food processing technology); 3) Financial and economic assessments, so as to measure the filiéres competitiveness; 4) An organizational assessment, with reference to internal organizational and management issues, policies and their impact on incentives; and external analysis in terms of the nature of the contract and relations between various organizations; 5) Issues of rural development were also tackled (p. 90).

This set of activities appears to be consistent with the environment, behavior, performance paradigm set forth by Shaffer (1980). Of particular interest is the explicit recognition in item 2 of technical innovation; many commodity-sector studies, despite their emphasis on vertical links, fail to examine performance in the research system that does or could generate the technical innovations and improved inputs to the commodity production processes.

3. Summaries of the Studies

3.1 Case Studies

The case studies are all concerned with the performance of component parts of the national agricultural research system. As such, they focus on national-level issues, costs, and impacts. In particular, investments in research in other countries borrowed by the home country are not counted in the cost calculation, nor are expenditures by international agricultural research centers or other regional and global research organizations.

3.1.1 Mali[1]

The Mali study was undertaken in the context of increasing evidence that rates of return (RORs) to investments in African agricultural research were positive and showed the impact of these investments, but that the overall performance of African agriculture over the past two decades is unacceptably poor. An underlying hypothesis is that the lack of well-functioning markets has limited the possibilities for technical advances to contribute significantly to agricultural transformation (even though these limited impacts may outweigh the costs of the investments). The Mali case study was designed to 1) assess the impact of maize varietal releases in southern Mali 2) determine the effectiveness of the subsector approach in defining market constraints and opportunities, and in helping NARS modify their research programs to take advantage of the opportunities and ease the constraints in ways that could increase the contribution of technical progress to agricultural transformation; and 3) to provide evidence on the role of input and output markets in determining the impacts of agricultural research and technology transfer.

Maize is the focus of the study because 1) in southern Mali, it is the only rainfed cereal with the potential for intensification, 2) improved varieties have been extended to farmers, 3) the geographic region in which maize is grown is well defined and tractable for fieldwork, and 4) the Malians were interested in how cereal-market reform influenced farmer adoption of technical advances.

Southern Mali is divided into two administrative zones corresponding to the parastatals charged with rural development: the Compagnie Malienne pour le Développement des Fibres Textiles (CMDT) and the Opération Haute Vallée (OHV). The CMDT was created in 1974 to take over Malian operations of the Compagnie Française pour le Développement des Fibres Textiles (CFDT), which had been operating in southern Mali since 1952. The CMDT maintains good links with the CFDT, and has preferential access to purchased farm inputs and agricultural equipment, and maintains farmer participation in rural development activities by using village organizations to provide local marketing services. In contrast, the OHV, created in 1964, is a much smaller and younger organization with less access to donor and national funds and markets.

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[1] This section draws heavily from Boughton (1995) and Boughton and Henry de Frahan (1994).

Each parastatal uses cotton as a cash crop and the basis for mechanization and improvement of the farming systems through technical innovation and human and physical capital accumulation. The differing history of the two organizations affects their accomplishments: for example, animal traction has been adopted by 75 percent of the farmers in the CMDT zone, but only 43 percent of those in the OHV zone.

Malian maize research began in 1964 under the auspices of the Institut de Recherches Agronomiques Tropicales et de Cultures Vivrières (IRAT). IRAT's resources were small relative to other West African countries, maize received only a small fraction of these resources, and maize research was limited to primarily varietal selection with some fertilizer work. In 1969 maize research was expanded, but emphasis remained on varietal improvement. In the 1980s the scope of maize research expanded and collaboration with other NARS members began in earnest. The CMDT also had its own varietal testing program, which became integrated with the national program following an outbreak of maize streak virus in 1983. Ten varieties were nominally available by the end of the 1980s, although two were distributed by the CMDT and not available nationally.

The CMDT decided to promote maize production as a way of increasing income-generating opportunities available to farmers and to ameliorate the chronic food deficits experienced during the early 1970s. Maize also has a place in eliminating seasonal food deficits occurring immediately prior to millet and sorghum harvest. The CMDT approach was to provide an integrated package that included seed distribution, credit, fertilizer, and until 1986, guaranteed output prices. Farmer profits from maize farming and adoption rates were high. The integrated approach was strengthened by Projet Maïs, implemented in 1980 with French funding. This project established and operated a seed-multiplication farm, subsidized equipment loans, and silo construction and storage depots. Even so, the integrated approach was costly:

> Although dramatically effective in terms of adoption rates, the integrated approach to maize production and marketing implemented by the CMDT was not financially sustainable. It required high subsidies on the part of the national grain board (which purchased the maize from CMDT), and the CMDT itself was subsidizing village-level collection of maize (Boughton, p. 59).

One dramatic consequence of the financial nonsustainability was that in 1985 when the national marketing parastatal ran out of money with which to purchase grain, the CMDT suspended its guaranteed prices to farmers.

The OHV essentially does not have a maize program in place. Dione (1989) reports that "no hybrid seeds of coarse grains are used (p. 152)" in the OHV zone.

Adoption of maize cash-cropping was much more rapid and intensive in the CMDT zone than in the OHV zone, although the total area planted to maize is small in either zone. The more rapid adoption in the CMDT zone is attributed to the better vertical coordination across input supply,

farm production, and output sales--as the OHV had no maize program, farmers were essentially on their own in terms of purchasing inputs or finding market outlets for their production.

The impact assessment portion of the study defined the innovation to be cultivation of maize. Prior to the CMDT program, there was some cultivation of maize in small parcels around the household, which tend to benefit from high organic matter and labor inputs, but little or no use of maize in the primary, outer fields. Consequently, the introduction of maize to crop production in the outer fields is an innovation to the farming system. The impact assessment quantified the benefits of this innovation relative to the alternative crops of millet and sorghum, which are traditionally grown on the outer fields. The comparison is made using enterprise budgets for each of the recommendation domains in which maize is grown, and contains both the OHV and CMDT regions. Costs of the investment in the development and use of maize cultivation include the research and extension costs from 1969 to 1990; any additional production costs are included in the enterprise budget analysis.

Results of the impact assessment show that the ROR to the investment in research and extension activities is 135 percent. By comparison, the highest, published, ROR to investments in Green Revolution technology in Asia is 133 percent (Oehmke). The high ROR is due in part to the high value of maize in a chronic or seasonal food-deficit situation, rapid adoption, and the low cost of research and extension due the reliance on spillovers of germplasm and technical recommendations from other West African countries and from regional research centers. The ROR is somewhat sensitive to price and yield reductions, sensitive to changes in the starting date, and is robust to changes in the total maize area.

The subsector analysis aspects of the study assess the prospects for expanding the urban consumption of maize and maize products, considering the role of output markets, and drawing implications for the design of research products. Key components of the analysis include a preliminary description of the commodity sector based on an informal survey, and market demand analysis based on a household-level survey in Bamako of consumer preferences and consumption patterns for maize and maize products. Analysis of the survey data indicates that demand for maize flour is price elastic and income inelastic; at any price, demand by women exceeds demand by men; consumers generally do not substitute maize flour for rice; and the establishment of an urban processing industry is not likely to have effects on aggregate demand for maize, in the short run.

Conclusions of the study regarding research planning include 1) maize production in Mali is too small to justify expansion of the varietal screening program into a varietal development program, and 2) greater emphasis should be placed on finding recommendations for profitable use of fertilizers.

3.1.2 Uganda[2]

The Uganda case study provides an illustration of the role of technology development and transfer in the oilseed sector in a country recovering from political turmoil. Endowed with favorable agroclimatic and edaphic conditions, at independence in 1962 Uganda was self-sufficient in food production, maintained a current-account surplus, and had established a viable private processing sector in cotton and edible oils that provided for domestic consumption and exported processed products to Kenya and Tanzania. The Amin regime witnessed the reversal of social and economic progress. Particularly devastating to the oilseed industry was the 1972 expulsion of Asians, including those who owned the oilseed processing capacity, and subsequent nationalization of this capacity. Government mismanagement, including lack of operating capital, price distortions, and inefficient cooperative management contributed to a decline in oilseed production to negligible levels by the mid 1970s.

Since the mid 1980s, there has been considerable domestic and donor interest in reviving the oilseed sector. The case study examines the role of technology development and transfer in this revival, including both realized impacts and potential impacts that can be realized through expeditious investment in key points of the oilseed sector. The case study contained both an impact analysis, with the objective of quantifying the rate of return to investments in technology development and transfer, and a commodity-sector analysis, with four objectives:

1. To assess the future demand for edible oil in Uganda and estimate the foreign exchange implications of continued importance.
2. To provide a comprehensive picture of the Uganda edible oil subsector in terms of capacity, flow of commodity, and number of actors.
3. To evaluate the relative competitiveness of the Ugandan edible oil subsector and identify the major constraints to improved efficiency.
4. To draw policy recommendations (Laker-Ojok, p. 11).

In this context, the term 'policy recommendations' includes the possibility of recommendations for public investment in or support of technical innovation at one or more stages of the commodity sector.

Development of the Ugandan oilseed sector began in 1929, when the first oil mill was established. Early development of edible oils was based largely on cottonseed processing. Due to early problems with quality control in the Ugandan cotton industry, the colonial government restricted cotton varieties and required all cotton seed to be purchased from government sources, and banned the use of hand gins. Ugandan peasant farmers were required to plant a minimum of 1/4 acre of cotton , with prices held artificially low. The processing industry was set up along oligopolistic lines, by

[2]This section draws heavily from Laker-Ojok (1994a, 1994b).

1) limiting cotton purchasing privileges to "established" ginning firms and their buyers (1913), 2) limiting the number of licensed ginneries (1922), 3) granting monopoly cotton purchasing privileges within a 5 mile radius of the ginneries, 4) establishment of regional ginners' associations that could set the cotton price for the entire province (1929), 5) imposing a legal ban on movement of cotton between association areas (1933), and 6) setting a government floor price that quickly became the maximum price under the influence of associations (Laker-Ojok, p. 71, citing Mamdani).

Despite this massive intervention, the edible-oil sector grew slowly during the 1930's, in part because of depressed world prices and in part because of its subsidiary nature to the cotton lint industry.

World War II brought dramatic increases in the British demand for food; the British government expected much of this demand to be met by its African colonies. Ostensibly to control inflation, the colonial government retained much of the increased earnings due to greater production and high war-time prices: for over a decade, more than 40% of the value of exports was retained by the government.

Peasant uprising in 1945 and 1949 in Buganda, expressly organized to break the colonial cotton and coffee monopolies, led to the establishment of a single ginning cooperative. While peasants nominally 'owned' the cooperative, real decision-making power rested in the hands of national marketing boards, to which the cooperatives were subsidiary. Investments in ginning capacity were restricted by government fiat until l 1953.

In 1953 the cotton sector was largely deregulated, with investment in ginning capacity allowed, and auction sale of all ginned cotton to local exporters. Cottonseed milling capacity over-expanded, until by 1965 the industry processing capacity (including that of non-operating firms) was 2/3 again as much as production. Some attempts were made at introducing sunflower as an alternative input for cottonseed mills, but the high local demand for sunflower and other edible oilseeds for direct consumption made this uneconomical.

The cotton industry, which in 1970 produce 20,000 t of cottonseed oil, was decimated by the Amin regime. By 1980 production of sunflower and cottonseed for crushing were negligible. The expulsion of Asians, who owned many of the cottonseed processing mills, led to a collapse in the processing capacity. While there has been some recovery in recent years, cotton and cottonseed production is a fraction of what it once was. In 1992, cottonseed production (in tons) was lower than production of each the other major oilseeds.

Renewed interest in oilseed production began in the late 1970 when the Catholic Church imported a small Chinese oil expeller and some Kenyan sunflower seed. Demand for oil was strong, and by 1986 a second expeller was added and a strong cash market for the oil had developed. Following, this lead, both the donor community and private entrepreneurs invested in processing capacity: between 1984 and 1992, 70 small to medium expellers had been purchased by 45 different

organizations. In 1988, ram presses were introduced. Currently, Uganda oilseed processing capacity is a mix of local small and medium expellers, presses, and various types of large-scale plants using large expellers or collections of medium expellers. Sunflower area increased from 5,000 ha or less in the early 1980s to 38,000ha in 1991.

Other oilseeds that could be used for processing include groundnuts (the most widely grown oilseed), sesame and soybean. Groundnut yields and area were lower in 1991 than in 1972. Soybeans have gained greatly in recent years, with 54,000 ha planted in 1991. However, most soybeans are roasted and eaten rather than processed. Moreover, soybean processing for oil is accomplished most efficiently through large-scale solvent processing, and profitability depends on the ability to sell the cake that is left after the oil is removed, usually to the livestock sector for animal feed. The Ugandan livestock sector is not yet at the level of development to constitute a viable market. Sesame is indigenous to north-eastern Africa. The dark-seeded sesame grown in Uganda has among the highest oil content in the world, but is usually grown for home consumption. Sale of sesame on the retail market is complicated by impure seeds, resulting in grain of varying color; inclusion of sand, stone and other impurities; and susceptibility to pests, shattering and other types of storage loss. Despite these difficulties, Uganda is one of the world's largest producers and exporters of sesame.

Research on oilseeds began with research on cotton, shortly after the turn of the century. Initially, emphasis was placed on staple length and uniformity. Smallholder productivity was not placed on the research agenda until 1937, but the emphasis was mainly on soil conservation and crop rotation techniques that were enforced by colonial legislation. After peasant unrest in the 1940s, the Namulonge research station opened in 1949. Research focussed on pest control, fertilizer use, and agronomic practices. Recommendations were disseminated through a broad-based extension service. Currently available varieties and recommendations could increase farm-level yields from 250-800kg/ha to one ton, but are not adopted. Cotton is currently grown by smallholders primarily as a cash crop and because of its roles in the crop rotation and as an intercrop with cereals or cassava. Recommendations based on monocropping, insecticide use, etc. do not fit into this farming system.

A considerable amount of research on sesame was undertaken after World War II, and apparently significant progress was made. In the political instability of the 1980s, most of the research results and genetic stocks were lost. Some reselection efforts from remaining materials have been undertaken, but as of the field study no improved varieties were available to farmers.

Soybean research has recently focussed on rhizobium inoculation and improved varieties. The varieties Nam 1 and L73 were released in 1991 and 1992, respectively. While these have only small affects on yields, they are more stress resistant than previous varieties. Rhizobium adoption is low, harmed by a poor extension service that has difficulty in explaining to farmers what exactly they are buying (since the package looks like a bag of dirt), and poor input distribution channels.

The specific innovations examined are the soybean variety Nam 1, the imported Sunfola sunflower variety, and the development and extension of the Ugandan hybrid sunflowers. The quantified impact of the Nam 1 soybean variety is a very modest increase in yields (five %); as noted above, the primary advantage of Nam 1 is improved storage characteristics, but data are insufficient to quantify the impacts of these characteristics. A small survey of sunflower farmers found a little over ten percent planted Sunfola (8 observations), obtaining yields over 1,400 kg/ha, more than twice the sample average of 600 kg/ha (60 observations). However, the small sample size calls into question the accuracy of these figures. Sunfola exhibits little yield advantage in on-station trials, and researchers feel its advantage is the higher oil content. Consequently, the impact of the Sunfola is measured as only the price increase due to higher oil content. The Ugandan hybrids have oil content comparable to the Sunfola, and yield 2-3 t/ha in on-station trials. The impact of adopting these varieties is measured as the price premium paid for the higher oil content, and an estimated yield advantage of 800 kg/ha under farm conditions.

The projected ROR to soybean research is negative for the period from 1985 through 1996. Important causes of this result are the lack of rhizobium adoption and the lack of quantification of storage benefits from the Nam 1 variety. The projected ROR to sunflower research, facility rehabilitation, training and extension is 31 %, for the 1985-1996 period. Sensitivity analysis shows that the estimate of a large, positive ROR is robust to different scenarios except ones in which the Ugandan hybrids have little or no yield advantage over local varieties.

Benefits not captured in the ROR estimates include the storability improvements in Nam 1, improved gender equity because women participate more fully in the production of soybean and sunflower than in other crops, and improvements in human and institutional capacity--which is especially important in Uganda in light of the political disruption of the early 1980s and consequent investment in rehabilitation.

3.1.3 Zambia[3]

The Zambia study evaluates the impact of investments in maize varietal research and related investments in extension, the seed industry, and marketing, by the Government of the Republic of Zambia (GRZ) and other research organizations and donor agencies from 1978 to 1991. Research led to the development and release of ten improved varieties in this period. The study quantifies the impact of these varietal releases and related investments, and examines the hypothesis that farmers' adoption decisions were critically influenced by an array of government policies, including subsidized fertilizer; pan-territorial, pan-seasonal producer prices for maize; establishment of a parastatal seed company; and direct provision of input and product marketing services. Of special interest in the study is the distribution of benefits between different producer groups, and between producers and consumers; and how the interactions among research, extension, and input distribution and marketing policy affected the returns to research.

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[3] Much of this section was contributed by Julie Howard; the remainder draws heavily from Howard (1995).

The context for maize production and research in Zambia is determined by the value of Zambian copper production. Agriculture is relatively less important in Zambia than in most SSA countries because Zambia has been a major exporter of copper on the world market. It is primarily because of this natural resource that Zambia was able to achieve growth rates of 12 percent per annum in the decade after independence in 1964. In 1965, mining contributed 41 percent of gross domestic product.[4] Employment in copper and other industries attracted people to urban areas in the Copperbelt and in the capital city, Lusaka. Building on colonial tradition, the GRZ was heavily involved in food production and marketing in order to assure a stable and inexpensive source of food for the urban population.

Maize is Zambia's most important crop, accounting for 70 percent of area planted and two-thirds of the value of marketed food. Maize farmers can be classified by size of farm. Small-scale farmers with less than five hectares cultivate maize primarily for subsistence reasons. Many of the men have migrated to work in the mines, leaving large numbers of smallholder households headed by women, cultivating maize with hand hoes and few external inputs. Of Zambia's 600,000 farm households, 75 percent are small-scale, covering 60 percent of total cropped area. Medium (5 to 20 hectares) and large farmers (over 20 hectares) are primarily cash farmers, using improved inputs and animal or mechanical traction.

Prior to independence, Zambia (Northern Rhodesia) relied on Southern Rhodesia for improved maize seed, the most notable variety being SR52. Following independence, Zambia initiated a national maize breeding program in 1962. During the first decade no significant improvements over SR52 were made. Starting in 1977, the Yugoslav Maize Research Institute supported the Zambia program by out posting two breeders, C. Jovanovic and D. Ristanovic. Observing heterogeneity in SR52 plants, Ristanovic investigated and found that because of improper maintenance of breeder's seed only five percent of the male parent cobs and 23 percent of the female parent corresponded to type. After cleaning the parent lines, the repurified SR52 exhibited a 20 percent yield increase, and in 1983 was released as Mount Makulu 752 (MM752). SR52 and later MM752 were the varieties of choice among farmers growing maize for commercial purposes, although many preferred traditional varieties for home consumption, largely because these varieties were flintier and had lower storage loss.

One of the disadvantages of MM752 for Zambian smallholders is that it is relatively long cycle (160-165 days to maturity). Smallholders tend to plant maize for market later than their subsistence crop, hand hoeing is difficult prior to the onset of the rains, and late planting reduces weeding labor. However, late-planted maize is susceptible to streak virus, and estimates of yield reduction are one to two percent per day of delay.

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[4] In the mid-1970s, a decline in world copper prices of 40%, rising petroleum-fuel costs, declining copper reserves and falling ore quality led to a decrease in mining's contribution to GDP to 14 percent by 1980.

Smallholder needs led Ristanovic and his counterparts to focus on early-maturing hybrids with improved drought tolerance and disease resistance relative to SR52. Between 1984 and 1988, one short-cycle (120-125 days to maturity) and seven medium-cycle (130-160 days to maturity) varieties were released; in 1992 another short-cycle hybrid was released. The Swedish International Development Authority (SIDA), one of the key donors to the breeding program, simultaneously funded the establishment of a semi-commercial seed parastatal, the Zambia Seed Company (ZAMSEED) . By encouraging linkages between the breeding program and ZAMSEED, rapid multiplication, distribution through an expanded farmer cooperative system, and adoption of improved varieties was encouraged.

The release of these varieties took place in the context of heavy government involvement in the maize sector, initiated in the 1970s and continued in the 1980s. Pan-territorial maize pricing had been in effect since the 1970-71 growing season. Fertilizer subsidizes, introduced in 1971 at about 30 percent of landed cost, reached 60 percent by 1982 and, along with donor contributions of fertilizer, facilitated a quadrupling of fertilizer use between the 1968 and the 1987. The establishment of local input supply and output-purchase depots and through the cooperatives facilitated access to the subsidies. In the 1970s, credit programs were expanded through the farmer cooperatives. leading to such strong relations between the hybridization program and the seed company that Ristanovic thought of himself as an entrepreneur in developing a product targeted for ZAMSEED needs.

Adoption of the released varieties was rapid and extensive. By 1992, nearly 60 percent of small/medium maize area was planted to improved varieties. Survey results confirm the importance of extension, timely local seed delivery, marketing and price policies in the farmers' decisions to plant improved varieties, and consequently the importance of these interventions in determining the impact of the genetic improvements.

The policy context changed dramatically in 1988. Government subsidies to the maize sector nearly reached 17 percent of the total government budget in 1988, not including research, extension and seed expenditures. Pressured by the World Bank and other donors, the GRZ reduced subsidies on some types of maize meal in 1986,[5] and ended fertilizer subsidies in 1988. However, there was little political commitment in the Kaunda government to meaningful reform. Following his election in 199,1 based on a campaign platform of subsidy reductions, President Chiluba implemented a structural adjustment program, with assistance from the International Monetary Fund (IMF). The 1991-92 drought delayed the initiation of maize marketing reforms until 1993, at which point the GRZ was to remove itself from marketing except to facilitate some private-sector efforts.

Impact assessment was accomplished by calculating RORs to the package of government investment that led to the development, dissemination, and use of the Zambian improved maize varieties. The time frame for the ex-post analysis is 1978 to 1992; the initial date reflects the start

[5] The subsidies were quickly reinstated following riots in major cities.

of major funding for the Zambian breeding program, and the ending date reflects data availability at the time of the field work. The ROR results are extremely dependent on how government investments in market development, including pan-territorial output pricing, are treated. If these costs are omitted, then the RORs to the remaining investments range from 99 to 114 percent (?). If the marketing costs are included, reflecting the idea that the market development may be an integral part of the adoption decision and consequently the impact of the maize research and extension, the ROR becomes negative.

Table 1. Estimated RORs to Investments in Zambian Maize

Activities Costed	**Rate of Return, 1978-1991**[a]
Research, extension, seed, marketing, and additional production costs	negative
Research and additional production costs	114
Research, extension and additional production costs	102
Research, extension, seed and additional production costs	99

[a] Based on Akino-Hayami method.

Source: Howard, adapted from Table 21.

Numerical simulation results suggest that the ROR to investments in research, extension and seed in the absence of marketing policies would have been substantially higher, from 126 to 139 percent. A critical variable in this simulation is the adoption rate that would have occurred in the absence of the marketing policies.

3.2 Conceptual Studies

3.2.1 Technical Innovation in a Commodity Sector

The model of technical innovation in a commodity sector posits a sequence of intermediate production activities, culminating in production of a consumer good or service. The production process at each stage is represented by a cost function that allows the value added in any stage of the sector to come from physical transformations of the product (such as transforming maize grain into meal), or from service-oriented activities such as marketing or transportation (although these also have characteristics of physical transformations such as changing the location of the product).

Technical innovation is introduced as a reduction in the unit cost of production at a particular stage in the commodity sector. The innovation may also affect production costs at other stages of the sector, perhaps by providing a better-quality intermediate product (such as a higher protein content in grain) that lowers the unit costs at later stages. Similarly, an innovation that is incompatible with the remainder of the commodity sector may raise production costs at other stages: for example, the application of pesticides may reduce on-farm costs but may raise the costs of compliance with residue standards.

The impacts of technical innovations are examined. The results confirm previous intuition: there are no magical solutions to the dilemma of how best to stimulate agricultural transformation. Technical innovations reducing the production costs of those intermediate products contributing most to value added in the sector are most likely to increase the sector's contribution to GDP, ceteris paribus. Immiserizing innovations are possible: innovations can increase returns at a particular stage in the sector, but diminish GDP. The immiserization can occur because of policy distortions at various stages of the sector, as in Bhagwati's original treatment of the subject, or it can occur if a particular innovation is incompatible with the remainder of the sector. The model exhibits behavior in which government subsidies at one stage of the commodity sector can stimulate innovations throughout the sector, in a vertical form of the 'narrow-moving-band' argument for infant-industry protection (Krugman).

The study shows how the model can be implemented using enterprise budgets.

The most significant drawback of the model and its implementation is that the treatment of consumer's surplus is somewhat artificial. This can be remedied by further extensions of the model, and by adding market or consumer-demand studies to the collection of implementation tools.

3.2.2 Economic Growth Targets

In this paper, Oehmke explores the implications for agriculture and agricultural research of a four-percent-per-annum target for aggregate economic growth. Proponents of this target legitimately argue that given population growth rates in SSA close to or in excess of three percent, an economic growth rate of four percent is the minimum sufficient to guarantee a significant improvement in the welfare of the next generation of Africans. Over the past three decades, failure to achieve four percent growth has led to diminution of personal welfare throughout SSA, for example as measured by per capita incomes.

To achieve the four percent growth target, modern development paradigms point to the need for investment in agriculture and agricultural growth based on intensification and technical progress. Oehmke investigates the potential contribution of agriculture to four percent growth by investigating two issues: What magnitude of stimulus from agricultural technology is consistent

with a four-percent growth target, and is it possible for African agriculture to generate a stimulus of the necessary magnitude?

To inform the first issue the paper presents a conceptual paradigm, based on recent development literature, showing the potential contributions of agricultural and natural resource (ANR) systems, and technological change in these systems, to broad-based economic growth. This paradigm shows that the contributions of agriculture include the provision of affordable food and other raw materials to the non-agricultural sector, and eventually the release of labor and capital from agriculture for employment elsewhere in the economy. In order for agriculture to make these contributions, intensification, innovation, and increasing reliance on markets are necessary.

The paper then specifies subtargets for agriculture and agricultural technology commensurate with a four percent economic-growth rate. Because agriculture stimulates aggregate growth through the release of productive factors and by decreasing the prices of food and other raw agricultural products, a growth rate in agriculture of 3 ½ percent is consistent with the four percent aggregate target. For agriculture to grow at this rate, technical innovation has to increase multi-factor productivity by almost two percent per annum. As the specific targets for agriculture are likely to be country specific, the paper contains a sensitivity analysis.

3.2.3 Agricultural and Industrial R&D

Dinopoulos presents a paper of agricultural and industrial R&D in the context of a model of endogenous growth. The purpose of the paper is to explore in more detail the contribution of research in general, and agricultural research and technology transfer in particular, to broad-based economic growth. The paper addresses questions of optimal growth, social returns to investments in R&D, and optimal public investment in R&D.

The paper is develops a dynamic, general-equilibrium model of Schumpeterian growth, fueled by agricultural and industrial R&D. Instantaneous production follows a sector-specific factors model. Growth occurs when R&D discovers an improved production process. Agricultural R&D is publicly financed, and discovers innovations such as high-yielding crop varieties. Industrial R&D is privately financed, and discovers superior processes, such as clean-rooms for manufacturing microchips. R&D employs only skilled labor. In each sector, the innovations arrive following a Poisson process; sectoral R&D employment determines the Poisson parameters. This neo-Schumpeterian approach to R&D emphasizes the scarcity of human capital, which is a major impediment to growth in many developing countries.

The steady-state exhibits investment in both agricultural and industrial R&D, and endogenous growth. Aggregate consumption and the allocation of skilled and unskilled labor across sectors is constant. Prices of final goods decline relative to wages.

The government can maximize aggregate, steady-state growth with appropriate investment in agricultural R&D. The optimal ratio of sectoral R&D activities depends on relative consumption of the final goods, and the productivity of R&D in each sector. Economies with high endowments of skilled labor will experience higher levels of aggregate growth and have greater investment in agricultural and industrial R&D.

Model results are related to the extensive literature that calculates social rates-of-return (RORs) to investments in agricultural and industrial R&D, using partial-equilibrium frameworks. The model indicates that these frameworks tend to overestimate RORs to public investments, due to neglect of income effects. An example from Senegal indicates that the upward bias may reach 25% of the estimated ROR.

The results of the paper have two important implications for the use of commodity-sector analysis to determine actual and potential research impacts. The first implication is that the contribution of agricultural research to aggregate economic growth is measured proximately by the effect of agricultural research on the growth rate of the value of the final goods and services produced in the commodity sector. Consequently, the use of enterprise budget analysis in conjunction with market or demand analysis may be a viable approach to determining the best use of public resources for agricultural research. The second important implication is that human capital constraints at the scientist level can be important in limiting the impact of both agricultural and industrial R&D.

4. Results and Lessons

A vision of improved economic performance and more rapid, broad-based economic growth in sub-Saharan Africa requires transformation of agriculture from a subsistence sector to one generating cash incomes and value-added products. Key components of this transformation are greater reliance on knowledge-based production systems, agricultural intensification, and a greater market orientation. The case and conceptual studies provide several lessons on the role of research in stimulating and supporting agricultural transformation.

4.1 Lessons about the Market Orientation of Agricultural Research

4.1.1 Augmenting Value-Added Activities

Even in the less-developed countries of sub-Saharan Africa, post-farmgate processing and distribution activities contribute as much as one-half of the value of staple food products. As development proceeds, the importance of value-added activities is expected to grow:

> The transition from an agricultural sector that supplies only unprocessed products, with all subsequent value added by consuming households, to one that supplies products with at least some of the subsequent services already incorporated, is fundamental to the process of agricultural transformation. (Boughton, p. 23)

In order to determine which value-added activities will be profitable, the private sector needs information concerning consumer preferences and willingness to pay, and appropriate technology for the value-added activity.

The importance of value-added activities to agricultural transformation has three implications for agricultural research: First, the design of research agendas needs to consider the post-farmgate activities that are or potentially might be contributing to agricultural growth, and the technological opportunities for improvement in these activities. Second, the commodity sector perspective, particularly with its emphasis on vertical slices of the agricultural sector, is well suited to provided information on technological opportunities. Third, the technical innovations and outputs produced using these innovations need to be viable in competitive markets, at least after a brief, initial learning process.

4.1.2. Demand-Driven Technology

The concept of demand-driven technology is that of a technological system and technical innovations emerging from that system that are responsive to the needs of clients and stakeholders of that system. This responsiveness is most notable in three areas. In research design, clients and stakeholders, or at least their needs and desires, are incorporated into the design process. In the

dissemination of technical innovations, market-demand forces are allowed to determine the level and intensity of adoption based on its profitability and how it fits with the needs and desires of the adopters. One way of fostering rapid adoption is by including clients and stakeholders in the testing of prototypes and other intermediate research products (as in on-farm trials) to learn their reactions and responses. The Mali and Zambia studies provide examples of how innovations that match farmers' needs and desires can lead to rapid adoption and significant changes in the farming system. They also show the financial nonsustainability of trying to develop farming systems based on government subsidy rather than market forces, and the continued adoption after the removal of subsidies perhaps helps to delimit the appropriate role of subsidization. The third area of responsiveness is meeting the needs of consumers and other demanders of the goods and services provided by the technical innovation. In Mali, the expansion of improved maize area and the contribution of maize production to agricultural transformation appears to be limited by the low demand for maize and maize products among urban consumers.

4.1.3 Identifying Clients and Stakeholders

The critical component of developing a demand-driven technology system is to identify who are the clients and stakeholders of the research and development activities. The Zambia case study illustrates both the difficulty of identifying and working with clients, and how an effective program can overcome this difficulty:

> "Significant technology advances have been achieved because of donor projects, but perhaps the price of assistance has been an unintentionally introduced confusion over who the real clients of the research system are. ... donor agencies have a different set of clients than national research systems; ... heavy reliance on outside funding sends confusing signals to researchers and partially blocks an avenue through which Zambian research clients -- farmers, consumers and industry -- can exert influence research priority-setting and implementation (Howard, p. 252)."

In contrast, the Swedish funding of both breeding and seed-industry development in a single project fostered the idea that the seed industry was a client of the breeders, motivating coordination among breeders and ZAMSEED. The strong relationship between the head breeder, Ristanovic, and ZAMSEED fostered the development of the short-cycle varieties desired by farmers, which contributed to the rapid adoption and use of these varieties.

More generally, there is need for identification of clients and stakeholders beyond the farm gate:

> "the ability to target the most important constraint areas where new technology is needed ... implies recognition of a broader set of research clients than farmers -- including consumers, and small- and large-scale industrial users -- and more effective participation by these clients in setting research priorities and monitoring research products (Howard, p. 250)"

These importance of working with clients and stakeholders also emerges as a lesson from the Mali and Uganda case studies.

4.2 Lessons about Markets

The availability of markets is critical to achieving broad-based impact. Greater reliance on markets is one of the characteristics of the transformation from subsistence to developed agriculture (Staatz). For example, lacking output markets of some sort, even farmers adopting high-productivity innovations remain subsistence farmers (tautologically, since there is no market for their surplus) and agriculture remains undeveloped. The deeper questions are: 1) Which markets are most critical (e.g. input or output, cash or food crop)? 2) Is the existence of well-functioning markets a precondition for technical impact, or can markets and technology develop simultaneously? and 3) What is the role of the public sector in the development of key markets? Fully to answer these questions is well beyond the scope of this study, but the cases do shed some light on these issues.

4.2.1 The Importance of Local Markets

The emergence of cash markets for agricultural products in urban centers is not sufficient to induce farmers to produce marketable surpluses. Farmers have to recognize financial incentives to invest in the production of commodities for sale, and there are a number of reasons why the existence of urban consumer demand may not provide adequate incentives. One is that local production may not be able to compete with imported products, particularly if the imports are subsidized (such as PL480 aid). A second is that the costs of transporting the surplus from the farm to the urban area may be prohibitive due to poor infrastructure, lack of a wholesaling industry, or simply lack of information about urban sales opportunities.

The emergence of local output markets provides farmers access to and information about using their farm to generate cash income. Successful local markets typically consist of the marketplace, vendors and buyers, and links via private or public wholesalers to urban centers or other areas of demand. These links are critical to the transformation of the agricultural sector.

The case studies provide fascinating examples of the importance of both urban and local markets. In the OHV zone of Mali, with the parastatal unable to provide adequate local marketing services, maize adoption was minimal and there was little marketable surplus. In the neighboring administrative zone, with similar agroclimatic characteristics, the CMDT acted as the local market for maize by purchasing it directly from farmers. Finding that they could grow maize profitably, farmers adopted maize production quickly. However, the CMDT's ability to expand its local-market participation was hampered by the small urban demand for maize and maize products, thus restricting the CMDT's ability to purchase large quantities of maize locally and still maintain

adequate profitability. Consequently the effective local market remains small, as do the impacts of the maize innovations on agricultural transformation.

In Zambia, "eighty-two percent of improved maize users got their fertilizer at local depots, 86 percent sold their maize there, and 80 percent purchased maize seed locally (Howard, p. 235)." The conjunction of input and output market policies and subsidies makes it difficult to determine from the Zambia study if a particular type of market or subsidy is sufficient to generate large impacts from technical innovation, or if the entire panoply is necessary.

4.2.2 Are Input or Output Markets Higher Priority?

Academic discussions of which markets are higher priority often follow chicken-and-egg logic: it isn't possible to produce marketable surpluses without access to inputs and input markets, but there is no incentive to produce a marketable surplus if there is nowhere to sell the surplus. Economic theory finds that input demands will be derived from the value of the outputs which the inputs produce, suggesting that markets which provide cash value for the outputs will be needed in order to make input markets effective.[6] Thus, priority would be placed on the development of output markets.

The case studies provide some empirical evidence on this issue. The evidence informs two distinct aspects of this issue: the rapidity and efficiency of the adoption and use of technical innovations, and the impact of those innovations.

The Mali case study clearly shows that the impact of the technical package distributed to farmers is limited by the lack of demand for maize and maize products.[7] In Mali, the limitation on the impact appears as the small area planted to maize--a peak of 90,000 hectares--with projections of future increases of no more than twenty percent. So even though the maize package was a technical and economic success for adopting farmers, the contribution of this innovation to agricultural transformation is limited by the size of the output market which it affects.

Examination of the history of cash-crop maize adoption in the CMDT zone further reinforces this point. To the extent that the CMDT is able to provide an output market, maize adoption has been

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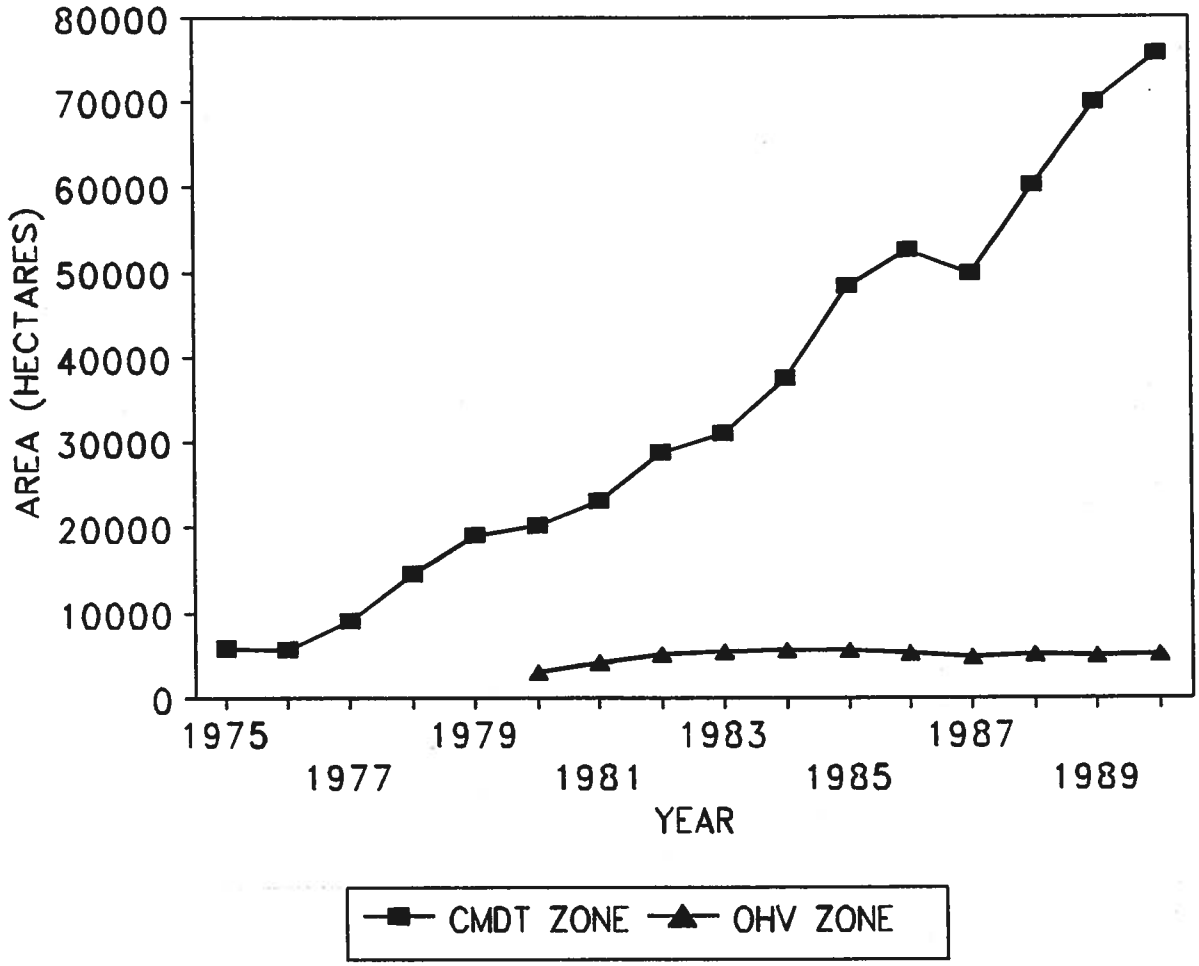
[6] The adage "Supply creates its own demand" applies more to an aggregate economy with existing markets, rather than the emergence of markets focussed on a particular commodity and the inputs needed to produce it.

[7] This is not the same as the lack of market infrastructure, knowledge of trading days, etc. that we interpret as a lack of markets. Nevertheless, if the lack of expressed demand for consumer goods based on the agricultural output translates into restricted impacts of the innovation, then the inability of markets to express demand will also translate into restricted impacts of the innovations.

Figure 3. Adoption of Improved Maize in Mali's CMDT and OHV Zones



Source: Boughton

rapid, and has even rebounded from the removal of output subsidies in 1986 (?). The adoption ceiling seems to be determined in large part by the lack of urban demand for maize and maize products articulated through private-sector markets, and the CMDT's lack of mandate to and/or success in stimulating urban demand through public-sector intervention because the maize products do not meet consumer wants and desires. Since the CMDT could easily provide the inputs necessary to double current maize production, it is clear that the constraint here lies on the output side.

The Mali study also shows that the rapidity and efficiency of adoption was positively influenced by the existence of well-functioning input markets. The telling evidence here is the difference in the rate and level of adoption across the CMDT and OHV zones. Through the rapid adoption, the input markets strongly contribute to the high estimated ROR. For example, the sensitivity

analysis indicates that a five-year delay in the adoption pattern would cut the estimated ROR nearly in half.

Synthesizing the implications of the Mali study, two conclusions are reached about the relative importance of input and output markets: 1) when neither input nor output markets function effectively, there is little adoption of technical innovation (evidenced by the OHV/CMDT comparison), 2) the existence of a reasonable input market or other supply mechanism is important to the adoption of innovations, 3) the contribution of these innovations to agricultural transformation is determined largely by the demand for the farm product as expressed through the marketplace, and 4) the existence of a well-functioning, input-supply mechanism for improved inputs is not sufficient to generate market demand for the output.

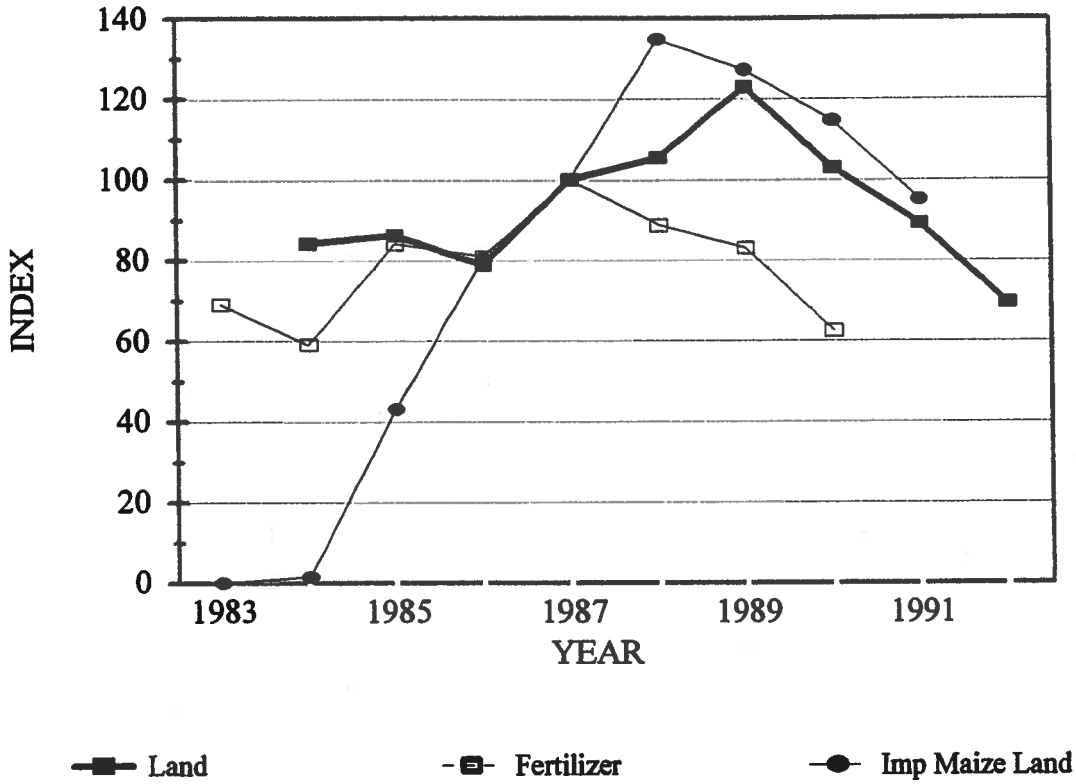
In Uganda, the key constraint to adoption of oilseed production and technical innovations is the lack of an effective output market for the oilseeds. Due to the reliance on inappropriate and inefficient cotton-seed processing equipment, and the availability of relatively cheap imports of edible oils, oilseed processors are able to compete in the domestic, edible oils market only if they pay low prices for oilseeds. At these low prices, farmers find no financial incentive to invest in oilseed production or innovations. Consequently, the oilseed sector remains backwards. This backwardness is due neither to the lack of technical innovation nor the lack of consumer demand for edible oil, but due to the inefficient oilseed-to-oil production process in Uganda and the subsequent lack of a farm-level market for oilseeds.

Interestingly, the progress that has been made to rectify the problems in the oilseed sector appears to be driven largely by the output market. The expansion of sunflower milling from a single small mill into a growing industry has been driven largely by the strong demand for the sunflower oil. It is in response to this demand that sunflower area has increased. The input supply mechanisms for improved sunflower production in Uganda cannot be called efficient yet, but it is clear that such mechanisms are developing in response to the demand for the product. This begs the fascinating question: Can a well-functioning output market and the existence of improved inputs stimulate the development of well-functioning input markets? While the evidence in Uganda is not yet complete, this certainly appears to be a possibility.

In Zambia, the government concurrently invested in establishing both input and output markets, and then disinvested in both; consequently it is difficult to establish the primary importance of either market. Rapid adoption of the repurified SR52, the short-cycle Zambian hybrids, and complementary fertilizer, was surely aided by the availability of these inputs in timely and low-cost manners. Similarly, the adoption of maize production itself was aided by the existence of both input and output markets. Following the government institutionalization of these markets, maize area nearly doubled; following government dismantling, maize area fell by nearly fifty percent.

The most interesting feature of the Zambian example is the use of maize hybrids relative to use of other inputs (?). Fertilizer use on maize peaked in 1987, and fell by nearly 40 percent between 1987 and 1990. Smallholder land in maize peaked in 1989, and fell by more than 40% between

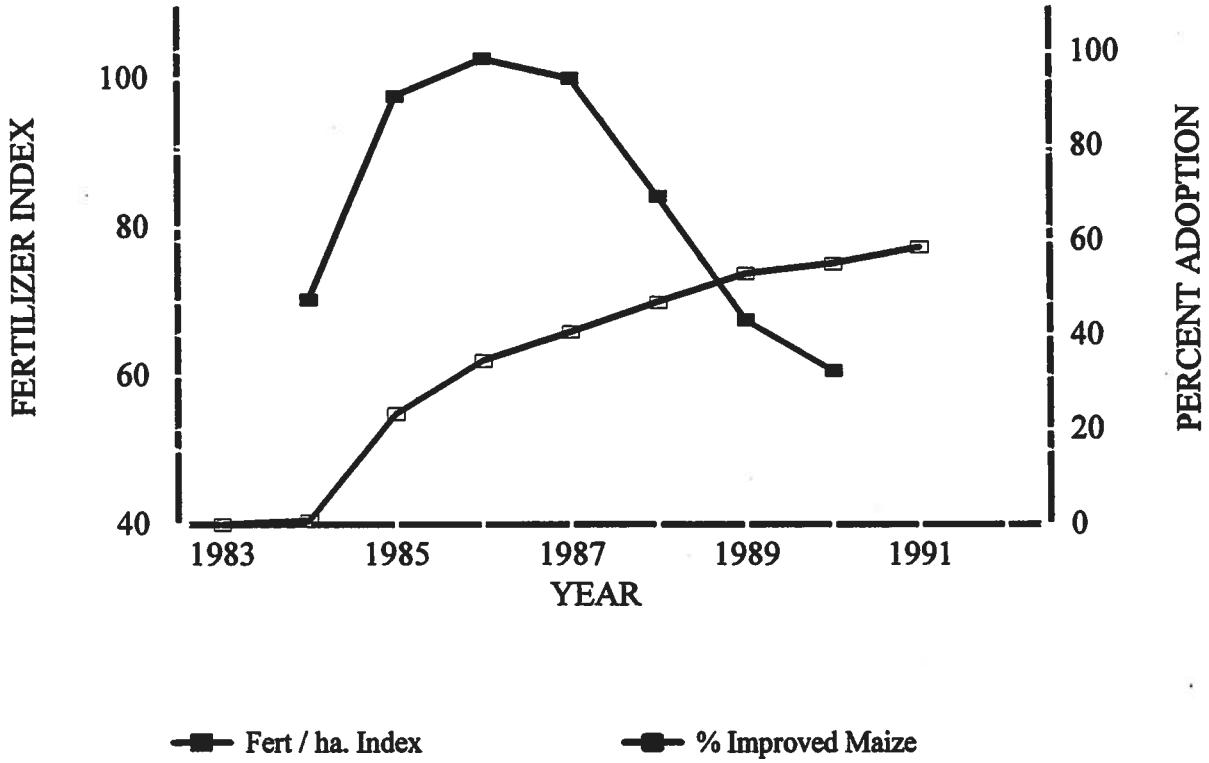
Fig. 2. Fertilizer applied to maize, smallholder land in maize, and smallholder improved land in maize; Zambia, index numbers, 1983-1992, 1987=100.



1989 and 1992, but remains closer to 1987 levels than does fertilizer use. Smallholder land in hybrid maize peaked in 1988, and has declined thereafter. However, the magnitude of the decline is less than with either fertilizer or total land in maize. Smallholder land in improved maize peaked in 1988, but the following decline has been smaller than with total smallholder land in maize or fertilizer use. This suggests that although the removal of subsidies has led to declines in the levels of inputs used in maize production, the innovation of improved varieties has been relatively less affected. Moreover, the continued use of improved varieties encourages the shift from a low-input, traditional production system to a high-input, improved variety maize production system.

Further evidence on the transition away from low-input, traditional-variety maize production is found by looking at improved variety adoption rates expressed in percentage terms (?). Area planted to improved Zambian varieties jumped from less than one percent in 1984/85 to 23 percent in 1985/86, primarily due to the release and sale of MM752 and other Zambian varieties. Adoption increased by eleven percentage points in 1986/87, and by about six percentage points

Fig. 3. Fertilizer use on maize, and smallholder area in improved maize, Zambia, 1983-1992.



each of the next three years. Increasing unreliability of the government-managed input and output markets contributed at most a slight diminution of the adoption rate, with area planted to improved varieties increasing by 2 percentage points in 1990/91 and 3 ½ points in 1991/92, to a high of 58.6 percent in that year (more recent data are unavailable). While it is doubtful the initial adoption pattern would be so dramatic without the government subsidization of input and output markets, this case shows that maintaining financially-unsustainable subsidies is not necessary for continued adoption and use of economically profitable innovations. In other words, the removal of the subsidies has caused a decline in the maize industry as exhibited by the removal of land from maize production, and a shift away from fertilizer-intensive techniques, as indicated by the decline in fertilizer use per hectare; it has not affected the intensity of use of improved-variety techniques, as demonstrated by the continued increases in adoption of improved varieties as a proportion of land in maize.

Contrary to the adoption of improved varieties as a proportion of area, fertilizer use per unit of land area declines dramatically after 1986 (?).[8] The question then arises, why did fertilizer use decline? Is it because fertilizer use is no longer profitable to farmers after the removal of subsidies and/or market outlets? One hypothesis is that the removal of the government purchasing depots and consequent decline of a cash market for maize led to the unprofitability of fertilizer use by smallholders. In contrast, the short-cycle hybrids have advantages over traditional varieties even in low-input subsistence agriculture. Consequently, their use continues even in the absence of a cash market for output. The data are insufficient to determine the veracity of this hypothesis, but available data are consistent with it. The hypothesis also has implications for the ability of technical innovations to stimulate agricultural transformation, and the importance of output markets as a complementary stimulus.

The following hypotheses emerge from the comparison of the three case studies: 1) the existence or development of input and output markets is critical to rapid and widespread adoption of technical innovations, particularly those designed for increasing marketable surplus; 2) the magnitude of the impact of a profitable and used(adopted) technical innovation is strongly influenced by the size of market for the output produced using the innovation; 3) well-functioning input markets and the availability of technical innovations do not guarantee the emergence of a well-functioning output market, and 4) the existence of a well-functioning output market and profitable technical innovations can stimulate the development of well-functioning input markets. These hypothesis are based on a small number of case studies and/or anecdotal evidence from informal follow-up. A great deal of additional investigation is required before the hypotheses can be regarded as established empirical facts.

4.3 The Role of the Public Sector in Market Development

The critical role played by agricultural markets in the onset and maturation of agricultural transformation raises the question: How can governments improve market conditions? In much of Africa, the recognition that markets are underdeveloped compared to the developed world has led many governments to intervene directly in the market system, for example by establishing parastatals, regulated cooperatives, marketing boards with monopoly powers, or other forms of government-run corporations. When these organizations are effective at their market activities, they provide a great boost to the adoption and use of improved techniques and capital accumulation, and thus to agricultural transformation. When they are ineffective, innovations languish unused, and/or the financial burden of maintaining the activities renders the organization

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[8] Fertilizer use is for all maize; the area in the denominator is smallholder maize area. Since smallholder area declined after 1989 and large-scale maize area increased, the graph is an overestimate of fertilizer use. Similarly, if large-scale farmers maintained their use of fertilizer after 1987 but smallholder use declined, then the graph will also tend to overestimate fertilizer use by smallholders. This suggests that the recent decline in fertilizer use by smallholders may be more severe than indicated by the graph.

or activity financially unsustainable. An apt example corroborating these conclusions is the comparison between maize adoption in the CMDT and OHV regions of Mali: the greater effectiveness of the CMDT allowed it pursue a maize program resulting in rapid and profitable farm-level adoption of intensified maize farming; the OHV was unable or unwilling to develop a maize program. Unfortunately, the CMDT was not able financially to sustain the growth of the output market, which has limited the contribution of maize cash-cropping to agricultural transformation in the CMDT region.

The evidence provides little support for government-controlled markets via parastatals or marketing boards. The most successful such organization studied is the CMDT--an organization which is at least semi-autonomous and seeks to make a profit while fostering rural development. In other words, the CMDT has many characteristics of a private corporation. The OHV has not performed so well, either in the maize sector or elsewhere (Dione). The maize price supports scheme funded by the marketing board and implemented by the CMDT was financially unsustainable, as was the pan-territorial pricing in Zambia. Financial unsustainability of output price subsidies for promotion of technical progress has also been noted by other impact studies, such as in Senegal (Schwartz, Sterns and Oehmke) and Sudan (Ahmed and Sanders). The lesson is that a poorly-functioning private market is not justification for the government jumping in head first. Governments can fail just as easily as the private sector.

The rules under which markets operate will also influence the magnitude and distribution of the impacts of technical innovations. For example, in Zambia maize prices were supported in the Kaunda government in order to appease urban consumers and generate political support. These subsidies clearly affected the amount of and manner in which maize was grown. The Chiluba government, as it engages in structural adjustment, has not provided these subsidies.[9] Consequently, maize area has declined. The impact of the maize research and varietal release program--on farmers, urban consumers, and subsidy costs--surely depends on how subsidies affect the rules for trading in the market. There is a legitimate role for governments to play in defining fair contracting, enforcement of grades and standards, and other rules that enhance the accessibility of markets for the small farmer or businessman.

Public subsidization directly affecting research has some role in an infant industry. In Mali, it seems unlikely that farmers would spontaneously choose to plant maize without CMDT intervention. In instances where the market is at least nominally established, the case for infant-industry protection is much weaker. One aspect is that if the research innovations do lead to rapid market growth, the cost of the subsidization or protection will skyrocket (usually these costs rise quadratically as a function of market size), leading to financial collapse.

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[9] The Kaunda government was moving away from subsidies--because they were not financially sustainable-- even though it disagreed with the IMF and did not implement structural adjustment programs.

The public sector does have a role to play in facilitating the development of effective private markets. Some of the public goods needed by private markets, such as physical and information infrastructure, are most appropriately provided by the public sector (see Ahmed and Donovan for a more detailed discussion of infrastructure).

Agricultural research is a public good, and governments do have a very significant role to play in using research and development to stimulate agricultural transformation (Oehmke, 1996). Governments in most developing countries, including those in sub-Saharan Africa, are underinvesting in agricultural research and related activities (IFPRI). Perhaps the most important lesson learned is that national governments need to exercise greater stewardship over their public-sector, agricultural research programs through increasedinvestments that respond to the needs of clients and stakeholders of these programs.

4.4 Methodological Lessons on Commodity-Sector Analysis

The commodity-sector approach is a useful perspective for assessing the impacts of research and development activities, and for describing how market forces (or the lack thereof) may affect the level and distributional consequences of these impacts. Analysis of the link between research and agricultural transformation, with its movement to a market-based agriculture, is especially amenable to a commodity-sector perspective focussing on vertical linkages between adjoining stages of the production system.

Initial implementation of the commodity-sector approach via rapid-appraisal techniques is an appropriate first step. The rapid appraisal results should characterize who the relevant clients and stakeholders are, and provide guidance for more in-depth investigations into leverage points of the commodity sector and how best to use these points.

The measures of performance often employed in commodity-sector analysis have been designed primarily with analysis of policies in mind, and are not yet developed to the point where they can provide the information desired for design of financially and economically sustainable research programs. For example, relying largely on traditional commodity-sector performance indicators, Boughton argues that market liberalization has not improved vertical coordination: "The picture that emerges is one of a thin and weakly coordinated subsector by contrast with the pre-market liberalization period (Boughton, p. 83.)" However, prior to market liberalization, a price support scheme for maize farmers collapsed because of bankruptcy, surely indicating severe incoordination. Consequently, a new set of commodity-sector performance indicators relating to research and its contribution to agricultural research is needed.

Conceptual studies suggest that this set of indicators could be based in part on enterprise budgets for the commodity sector, economic surplus measures, and quantifications of the relationship between the public-sector research and private-sector firms. Some form of enterprise budget was

used to good advantage in each of the case studies. Further development of performance measures is a key area for future work.

5. Summary and Conclusions

This study is concerned primarily with drawing lessons about the use of the commodity-sector approach to assessment of impacts from technology development and transfer. In this sense, much of the activity was methodologically oriented. The major methodological findings are:

- The commodity-sector perspective, with its emphasis on vertical linkages, can contribute to impact assessments.
- The major contribution of the commodity-sector approach in *ex-post* assessment is the recognition of the roles played by input and output markets.
- The major contribution of the commodity-sector approach in *ex-ante* analysis is in the determination of leverage points in the commodity sector.
- The commodity-sector approach is compatible with neo-classical performance measures, and applied commodity-sector analysis would benefit from greater reliance on such measures.
- A commodity-sector performance measure relevant to assessing the impact of technical change in the sector on aggregate economic growth is the contribution of the technical change to the growth in gross domestic product originating in the commodity sector.
- Available measures quantifying the impact of technical change in a commodity sector on aggregate growth through linkages or multipliers are generally *ad hoc* and not closely tied to a relevant growth theory.
- The derivation of enterprise budgets for the various stages of the commodity sector, including how technical innovation has or might affect these budgets, is perhaps the most critical step in executing a technology impact assessment through commodity-sector analysis.
- Analysis of enterprise budgets may need to be complemented by market or consumer-demand studies.

In addition to the methodological findings, some interesting development results arise:

- The interactions among technical innovations and markets strongly affects the magnitude and distribution of impact.
- Output markets appear to be more critical than input markets in determining the magnitude of impact on agricultural transformation.
- The existence of a well-functioning input market is insufficient to generate demand for the output. The existence of a well-functioning output market may encourage development of an input market or other supply mechanisms.
- Farmers, particularly smallholders, who use markets tend to rely on local markets.

Commodity-sector analysis, implemented as described above, is currently a viable tool for assessing the impacts of technology development and transfer activities. However, there are areas in which additional methodological work is needed. Perhaps the key to further advances in methodology is to recognize that "thinking of the package of technology and institutions which create the means and the incentives for all the relevant actors in the system to improve their productivity is more effective than focusing on an isolated innovation or policy (Shaffer, 1996)." Yet this thought process is consistent with the delineation of those leverage points that can provide the greatest stimulus to agricultural growth, and an emphasis on specific innovations. The critical idea is that the discovery of bottlenecks or opportunities where an innovation can be used to leverage growth throughout the commodity sector is made by examining the system rather than an isolated point, but that once the leverage points are discovered the innovative work can focus on and target these particular bottlenecks or opportunities.

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