WORKING PAPER No. 7

PRIORITY-SETTING MECHANISMS FOR NATIONAL AGRICULTURAL RESEARCH SYSTEMS: PRESENT EXPERIENCE AND FUTURE NEEDS

International Service for National Agricultural Research

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George W. Norton and **Philip G. Pardey**

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International Service for National Agricultural Research

ISNAR WORKING PAPERS

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2. They are intended to be an effective vehicle for widening the discussion of continuing work, thereby increasing the quality of the final products; critical comment is welcomed;

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The series is intended mainly for the diffusion of materials produced by ISNAR staff, but it is also available for the publication of documents produced by other institutions, should they wish to take advantage of the opportunity.

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Priority-Setting Mechanisms for National Agricultural Research Systems: Present Experience and Future Needs

Recent trends towards shrinking real research budgets for many national agricultural research systems (NARS) have stimulated several attempts to evaluate the economic benefits of agricultural research. Many of these quantitative economic evaluations have employed historical data to provide ex post assessments, and a few have used subjective judgments to project future research benefits.[1] The results of these analyses have been used at the national or inter-ministerial level to justify the need for continued political support for agricultural research.

Tighter research budgets not only heighten the need to justify agricultural research vis a vis alternative public investments, but they also make it important for NARS to improve procedures for setting priorities among competing research programs. A variety of strategic and project-level decisions are made within NARS. The objectives of national policymakers, the needs of agricultural producers, and scientific opinion must each be brought to bear on strategic decisions to emphasize particular commodities and research program areas and on research project selection.

The purpose of this paper is to discuss key elements for inclusion in improved research priority-setting procedures for NARS. The focus is on methods for strategic as opposed to more tactical, project-level decision making. After discussing the context of research priority setting, a brief summary is provided of the main types of research resource allocation methods. Recent experiences with priority setting in four Latin American NARS, the Dominican Republic, Ecuador, Uruguay, and Peru, are compared. These experiences can provide some guidance for the development of an improved research resource allocation procedure.

I. THE CONTEXT OF RESEARCH PRIORITY SETTING

NARS decision makers, often operating within the ministry of agriculture, an agricultural research institute, or as a research council, make allocative choices based on their knowledge and prior experience. That knowledge and experience frequently includes an understanding of national and regional goals and objectives as voiced through the political process, a sense of the severity of particular types of research problems, and a general feel for what is achievable through research. It also includes an awareness of the desires (often pressures) of producer groups. Decision makers must decide how much emphasis to place on particular commodities (e.g., rice, maize, beans, sheep) and types of research (e.g., varietal improvement, improved livestock nutrition, plant protection, farming systems). Implicit in those decisions are the locational emphasis of research; the focus on particular factors of production (e.g., land, labor, water); the emphasis placed on longer-term basic versus shorter-term applied and adaptive research; and the distributional effects of research on farm size, on producers versus consumers, and on people at different income levels.

In many NARS, research resource allocation decisions are heavily influenced by the previous year's budget.[2] Changes often result from requests by scientists, which are evaluated relatively informally and aggregated into an overall plan.[3] The resulting plan,

upon close scrutiny, may contribute little to the attainment of stated national goals and objectives.

Judgment based upon prior knowledge and information provided by scientists is crucial for research resource allocation decisions. In addition, rapid or radical changes in research programs can be costly.[4] Particularly as research budgets tighten, however, forcing changes in the system, the increased use of quantitative methods may be necessary to improve the objectivity of those judgments. The aim is to foster consistency of research priorities with goals and objectives and to improve the efficiency of the research system in meeting producer and consumer needs. The idea is not to replace judgment but to increase and organize the information available for updating prior knowledge and beliefs. The hope also is to inject continuity in the priority-setting process and to provide NARS decision makers with methods they find helpful when rationalizing their decisions to scientists, producer groups, and politicians. Documenting the decision process through a structured procedure can help minimize the possibility of sudden and large shifts in research priorities in those systems characterized by a fairly rapid turnover of research administrators.

Many quantitative priority-setting procedures are available but few have been institutionalized into the decision-making practices of NARS managers. A crucial factor in their non-use of these procedures undoubtedly has been the lack of rigorous yet cost-effective approaches which can incorporate the large number of commodities and research areas, as well as the multiple goals and criteria found in most strategic decision-making situations in NARS. Furthermore, the computer capability available through microcomputers in most developing-country NARS today was not generally available even two or three years ago.

In this paper, procedures are described which were recently applied in four Latin American countries. First, however, previously employed priority-setting mechanisms are briefly reviewed and critiqued. One of the points that will be made at the end of this paper is that these methods are not mutually exclusive. There is no single "magic bullet", but there appears to be real potential for developing a flexible, computer-assisted priority-setting framework that will allow NARS administrators to call on the appropriate techniques to assist with a particular decision, depending on the time and financial resources available and the relative importance of the allocation decision. A second major point is that priority setting is a process, not simply a procedure, and must be institutionalized as part of the overall process of research management. Priority-setting techniques applied only once by people outside of the decision-making process have little value.

II. SUMMARY OF PRIORITY-SETTING METHODS

Methods reported in previous studies for research priority setting include:

1) establishment and weighting of multiple criteria for ranking commodities and research areas with a final aggregate ranking based on implicit or explicit weights;
2) use of benefit-cost analysis, including expected economic surplus techniques, to select commodities and research areas;
3) application of mathematical programming to choose an optimal research portfolio incorporating multiple goals and constraints;
4) development and use of simulation models.

These four approaches are discussed below, followed by a brief assessment of their advantages and disadvantages.

Weighted Criteria Models

Several studies have established multiple criteria for ranking priorities because of the desire to explicitly consider a wide variety of factors that do, or perhaps should, influence research selection. The relative weights attached to each criterion to arrive at a final list of research priorities are sometimes left implicit or unstated. A recent example is the TAC review of priorities and future strategies for the Consultative Group on International Agricultural Research (CGIAR). In assessing priorities by commodity, they established a principal goal, research objective to obtain the goal, and a series of criteria organized into three groups: relevance, research productivity, and efficiency of the CGIAR system in undertaking research. Detailed tables with quantitative and qualitative information and rankings of commodities for each criterion were presented. In developing the recommendations for short- to medium-term funding alternatives at the commodity level, the weights used to aggregate across criteria were left implicit.

There are examples of studies that have incorporated multiple criteria but also explicitly specified and utilized a set of weights to aggregate across criteria and obtain a final ranking of research priorities. Applications of this method, often called the scoring model approach, are found in studies by Williamson, Mahlstede, Paulsen and Kaldor, Shumway and McCracken, and Von Oppen and Ryan. A few studies have used congruence analysis, which can be thought of as a special case of a scoring or weighted criteria model, with all the weight placed on the criterion of value of production.

Benefit-cost (Expected Economic Surplus) Analysis

The benefit-cost approach to selecting research priorities has been used in different forms (Fishel, Araji, Sim, and Gardner; Davis, Oram, and Ryan; Norton, Ganoza, and Pomareda). Most studies have employed consumer-producer surplus analysis and have built upon a large body of literature on ex post research evaluation. Ex ante analyses usually incorporate expert opinion to determine projected research impacts, adoption rates, and probabilities of research success and provide estimates of the economic efficiency and distributional implications of agricultural research resource allocation. Benefit-cost studies typically calculate benefit-cost ratios, internal rates of return, and net present values for alternative types of research or for research on different commodities. These analyses may or may not include regional and international research spillovers and the effects of domestic pricing policies on research benefits.

Mathematical Programming

Mathematical programming is another alternative for research selection. It relies on mathematical optimization to choose a research portfolio through maximizing a multiple-goal objective function, given the resource constraints of the research system. A good example of the use of this method is a study by Russell in the United Kingdom. He used goal programming to maximize the contributions of the research program to several goals, given the constraints of budget, human resources, state of knowledge, and certain policies. This procedure uses similar information to the weighted-criteria model but selects an "optimal" research portfolio rather than simply ranking research areas.

Simulation

Finally, the simulation method has been used to identify and select research priorities. Simulation models vary in their construction, but a good example is the model by Pinstrup-Andersen and Franklin. They built a model to project the contributions and costs of alternative research activities. They established goals and then identified changes in supply, demand for inputs, and demand for output needed to meet those

goals. They identified needed technologies, time and financial costs, and the probability of research success and adoption. Finally, they specified the scientists' working objectives. This model is very thorough but did require extensive amounts of data and estimation of several mathematical relationships.

Comparative Assessment

The above discussion is a brief summary of the major structural approaches that have been used to assist decision makers in research priority setting. All of them attempt to go beyond the usual procedure of individual or group decision making without structural analyses. Each of the approaches has its advantages and disadvantages. (See Table 1).

The procedure of establishing criteria and using weights to arrive at a final set of research priorities has the advantage of forcing decision makers to consciously trade off multiple goals. It can incorporate both quantitative and qualitative information and can be applied to a long list of commodities or research areas in a relatively short period of time. The procedure is relatively easy for administrators to understand, but does require their time in obtaining the explicit weights for criteria. Furthermore, these weights are inevitably subjective, and their elicitation must be carefully structured. The method also requires scientists' time in collecting information on qualitative criteria. As a result, the approach is better suited for periodic or major priority-setting efforts than for situations where frequent marginal changes are anticipated.

The expected economic surplus approach has the major advantage of incorporating several criteria related to economic efficiency and distribution into one or two measures. It also can be used to examine the general equilibrium effects of research (Ramalho de Castro and Schuh) and the benefits of research under alternative, possibly distortionary, domestic pricing and international trade policies (Edwards and Freebairn; Alston, Edwards, and Freebairn; Norton and Ganoza, 1985). These factors are pervasive in developing countries and affect the efficiency and distributional consequences of research. The procedure requires a higher level of understanding of economic analysis, and more analyst's time than the weighted criteria model, but less administrators' time. It can be difficult to apply to a large number of commodities or research areas because certain types of data necessary for the analysis often do not exist for all commodities. With adequate data, expected economic surplus analysis can be incorporated into the weighted criteria model or could be used on the set of commodities which the weighted criteria model indicates to have the highest priority. The latter approach would allow for the calculation of income foregone as a result of placing weights on non-economic efficiency criteria. Expected economic surplus analysis has the major advantage of calculating a rate of return which can be compared to alternative public investments.

The mathematical programming approach is similar to the weighted criteria model approach because weights are placed on a set of goals or criteria. The procedure has the advantage of explicitly considering the budget, human resource, and other constraints on the research system. Unless the constraints are well specified, including possible changes over time, however, there is a risk of nonsense solutions. The model is more intensive of an economic analyst's time and ability than the simpler weighted criteria approach, and decision makers may be less willing to accept what appears to be a "black box" solution. Trade-offs among goals are easily quantified with this approach.

The advantage of simulation models is their flexibility. They can be constructed as relatively simple or complex tools, can incorporate optimizing or ranking procedures, and can readily include probabilistic information. Their major disadvantage is that to be useful they must be relatively complex and typically require extensive amounts of both data and time of skilled analysts.

TABLE 1. COMPARISON AMONG MAJOR AGRICULTURAL RESEARCH PRIORITY-SETTING METHODS

CHARACTERISTIC	PRIORITY-SETTING METHOD			
	WEIGHTED CRITERIA	EXPECTED ECON. SURPLUS	MATH PROGRAM.	SIMULATION
OPERATIONAL CONSIDERATIONS				
1. Relative cost in researcher's time	medium	medium	medium	high
2. Relative cost in priority setting analyst's time	medium	medium	high	high
3. Relative cost in administrator's time	medium	medium	medium	medium
4. Relative overall data requirement	medium	medium	medium	variable
5. Relative ease of comprehension by decision maker	high	medium	low	low
6. Ease of incorporating subjective information	high	high	high	high
7. Ease of incorporating non-quantitative information	high	low	low	medium
GOAL-RELATED ISSUES				
8. Requires explicit elicitation of goals	yes	usually	yes	usually
9. Can determine distributional affects on consumers and producers at various income levels	no	yes	no	yes
10. Can handle uncertainty	yes	yes	yes	yes
11. Can consider tradeoff among multiple goals	yes	sometimes	yes	yes
CRITERIA-RELATED ISSUES				
12. Can consider private-sector research incentives	yes	difficult	difficult	yes
13. Can consider economic policy and trade effects	yes	yes	yes	yes
EVALUATION-RELATED ISSUES				
14. Can be used to set priorities for research at the aggregate level	no	yes	no	yes
15. Can be used to set research priorities at the commodity level	yes	yes	yes	yes
16. Can be used to set priorities for non-production or non-commodity oriented research	yes	difficult	yes	yes
17. Can be used to set priorities for basic research	yes	difficult	no	sometimes
18. Can evaluate secondary impacts of research on employment, environment, nutrition	yes	sometimes	sometimes	yes
19. Usually estimates a rate of return to research	no	yes	no	sometimes
20. Can quantify geographic spillover effects	no	yes	no	yes
21. Can consider the lags involved in research and adoption	yes	yes	yes	yes
22. Facilitates priority setting when the number of commodities is large	yes	difficult	difficult	difficult

Source: Adapted and modified from Norton and Davis

The above is a very brief summary of the major advantages and disadvantages of the most common formally structured priority-setting models that could be used for strategic planning for research resource allocation.[5] Other approaches exist for research *project* selection, with perhaps models that attempt to identify and analyze key yield constraints being the most prevalent approach employed in NARS of less-developed countries.[6]

The results of ex post analysis also can provide useful guidance for ex ante research resource allocation decisions if appropriately incorporated into a systematic ex ante procedure. The most common ex post approach, in addition to ex post benefit-cost analysis, is the econometric estimation of production or supply functions incorporating research variables. To be most useful for ex ante analysis, econometric approaches must be applied with a high degree of disaggregation. Unfortunately, these models require a substantial amount of high-quality historical data on production, farm inputs, and research expenditures.

Perhaps the two approaches with the most potential, given additional refinements, for application by NARS in less-developed countries are the weighted criteria models and the benefit-cost or expected economic surplus procedures. In the next section recent experiences with applying weighted criteria models in three Latin American Countries: Dominican Republic, Ecuador, and Uruguay are discussed and evaluated. The purpose is to provide more information about the procedures, their degree of acceptance, and possible improvements in the models. Then application of expected economic surplus models are considered, drawing on a recent ex ante research evaluation study in Peru. Finally, the relationship between weighted criteria and expected economic surplus methods is described along with possible extensions.

III. THE USE OF WEIGHTED CRITERIA MODELS IN THE DOMINICAN REPUBLIC, ECUADOR, AND URUGUAY

In 1986 and 1987, weighted criteria models were developed and implemented in the Dominican Republic (ISA), Ecuador (Espinosa et al.), and Uruguay (CIAAB) to assist with priority setting for agricultural research. In the Dominican Republic, the study was carried out at the Instituto Superior de Agricultura (ISA) by consultants for ISNAR. In Ecuador, the study was conducted by the planning office of the Instituto Nacional de Investigacion Agropecuaria (INIAP), with the assistance of consultants for the U.S. Agency for International Development (AID). In Uruguay, the study was conducted by the Office of the Director of the Centro de Investigacion Agricola 'Alberto Boerger' (CIAAB), with the assistance of ISNAR. The purpose of all three studies was to apply procedures for prioritizing agricultural research by commodity and by major research area. In the Dominican Republic, the client was the newly created national agricultural research agency (IDEA). In Ecuador, the client was INIAP and the newly created foundation for agricultural research (FEDIA). In Uruguay, the client was CIIAB.

The procedures employed in the three studies were similar but with some important differences, as the Ecuador study built on lessons learned in the Dominican Republic and the Uruguay study built on other lessons learned in Ecuador. National goals for the research system were elicited in each country and a series of criteria established which relate to those goals. Separate criteria were developed for commodities and for research areas, and weights were elicited from decision makers to establish the relative importance of the criteria. Commodities and research areas were ranked according to each criterion and these rankings were multiplied by the elicited weights to arrive at research priorities.

Goals

Three goals were identified in each of the three countries: (1) to raise the average level of income in the country, (2) to increase the well-being of low-income groups in society, and (3) to reduce year-to-year income fluctuations in the country, especially on the downside. These goals were worded slightly differently in each country, but in each case they essentially relate to the three goals referred to in previous studies as "efficiency", "equity", and "security" In the Dominican Republic, the local consultants identified these as the goals, while in Ecuador and Uruguay it was done by the directors of national research agencies.

Criteria

The next step was to establish criteria to use as measures of whether particular commodities or research areas contribute to the attainment of the above goals. A large set of criteria was discussed in each country, and a total of 15 criteria were eventually used in the Dominican Republic, 14 in Ecuador, and 10 in Uruguay, to determine priorities by commodity. Five criteria were used in each case to determine priorities by research area. Refinements were made in successive studies - beginning with the Dominican Republic, then Ecuador, followed by Uruguay - to increase the independence of criteria and to remove criteria that were questionable measures of whether research contributed to the stated goals. (Reasons for dropping particular criteria are discussed below.) Refinements also were made with respect to the grouping of criteria to facilitate the weighting of goals and criteria.

Commodity Criteria. Commodity criteria were grouped into four conceptual groups: product importance, probability of success, efficiency in use of research resources, and distribution of impacts. The first three of these groups relate to the efficiency or income level goal and the last group relates to the equity or distributional goal. In none of the three studies were criteria included which represented the third goal (reduced income fluctuations). The feeling was that the entire set of criteria as a group would serve to reduce the emphasis placed on a single or few (often export) crops. While this appeared to be the case in the results of these particular studies, future weighted criteria studies may want to add criteria which explicitly rank commodities from lowest to highest with respect to annual gross income variability (or price and yield variability separately).

The group of criteria referred to as *product importance* contained four criteria in the Uruguay study: value of production, generation or saving of foreign exchange, expected future demand change, and comparative advantage.

The value of production is an important criterion because the cost of research is basically independent of the number of units affected by the research results, at least for those commodities with relatively homogeneous production conditions. Foreign exchange was used as a criterion because of a perception in each country that the lack of foreign exchange was impeding growth. A criterion was set up to allow more weight to be placed on those commodities for which demand is expected to increase in the future, because the importance of commodities will change as diets are altered with income growth and as world markets change. Comparative advantage was included because income in the country will be higher if the country focuses its efforts on commodities for which its resource base is best suited, while recognizing that research itself can alter resource constraints.

In the Dominican Republic and in Ecuador, nutritional measures (calorie and protein contributions to the diet) were included as criteria for product importance. They were included because the well-being of low-income groups may be affected by the availability

of foods which are important in their diets. Nutritional criteria were dropped in Uruguay however, because numerous studies have shown that income levels are the primary determinants of nutrition levels rather than the availability of particular foods. Certainly, calorie and protein content are debatable criteria. To the extent that increased domestic production lowers the prices of certain food commodities, thereby increasing food consumption by the poor, nutritional criteria can contribute to the distributional goal. Land area also was included as a criterion in the Dominican Republic study but was dropped in Ecuador and Uruguay because of the overlap with value of production.

Two criteria were used in each study to measure *probability of research success.* The first measure was the gap between own-country yields and neighboring country yields. The second was the potential for success indicated by the researchers themselves. The rationale for the gap criterion was that the larger the yield gap between the home country and similar countries, the greater the potential for yield gains. The criterion is rather crude because yield gaps also can indicate a relative resource disadvantage for producing the commodity, even if the countries appear to be geoclimatically similar. Consequently, the gap criterion was eventually dropped in the Uruguay study. The potential for success, as indicated by the researchers, is subjective, but a very necessary measure to obtain.

The group of criteria referred to as *efficiency in use of research resources* contained three criteria: the relationship to research in the international centers, the degree of emphasis on the commodity in the current research program, and the incentive for the private sector to conduct the research. Some research duplicates, other research complements, and still other research bears no relationship to research at the international agricultural research centers. For certain commodities, all three relationships may hold depending on the type of research. If national research is complementary to international research, the cost of the national research is lower. Consequently, a criterion was established which places greater weight on commodities with a high degree of complementarity between national and international research. The criterion of degree of emphasis in the current research program was established because there is a cost to rapidly adjusting current human and physical research resources from one commodity to another. The criterion of private-sector incentives was used because the social benefits from the total research program in the country will be greatest if scarce public research funds are devoted to research on commodities for which the private sector does not have an incentive to support the research itself. Of course, the private-sector producer group can tax itself and pay the public sector to conduct the research for those commodities for which it has an incentive to privately support the research. These commodities tend to be export commodities, because producers can capture a higher proportion of the gains from productivity increases for export commodities than for commodities primarily consumed domestically.

The group of criteria related to the *distribution of research impacts* contained two criteria in the Uruguay study: number of producers and the effect of increased productivity on the price of product. The larger the number of farms producing a commodity, the larger the number of farmers affected by the research and perhaps the higher the probability that smaller farmers are being affected. The distribution of benefits depends to a significant degree on price changes resulting from increased productivity. Producers benefit more if prices decline very little, and consumers benefit more if prices decline substantially for a given production increase. For export or import commodities, prices will tend to decline less than for commodities primarily produced and consumed domestically. For commodities which are not traded and are very important in the diets of the poor, prices will tend to decline relatively sharply when productivity increases. The division of benefits between producers and consumers also is affected by the fact

that producers are also consumers. Consequently, in the Dominican Republic and Ecuador studies, an additional criterion, importance of the commodity in home-consumption on the farm where produced, also was included.

In summary, 10-15 criteria were used in the three studies to identify and select research priorities by commodity. The linkages among the goals and criteria described above are summarized in Figure 1.

Research Area Criteria. The five criteria used to select research priorities by research areas were (1) whether the research causes an increase in the use of relatively abundant resources and a saving of relatively scarce resources, (2) the number and severity of research problems, (3) non-duplication with transferable research from outside the country, (4) the extent of private-sector incentives to conduct the research, and (5) current emphases in the research program.

The rate of economic growth will be more rapid if new technologies are developed that utilize relatively abundant resources and save relatively scarce resources. The resource base varies by region; consequently, information on resource abundance criteria was collected by region in the Ecuador and Uruguay studies. The same was true for the quantity and severity of research problems. Information on the relationship of domestic to international research, private-sector incentives, and the current emphasis in the research program was collected on a national basis. These criteria all relate to the income growth (efficiency) goal. It is difficult to identify research area criteria that measure whether particular types of research affect income distribution or variability.

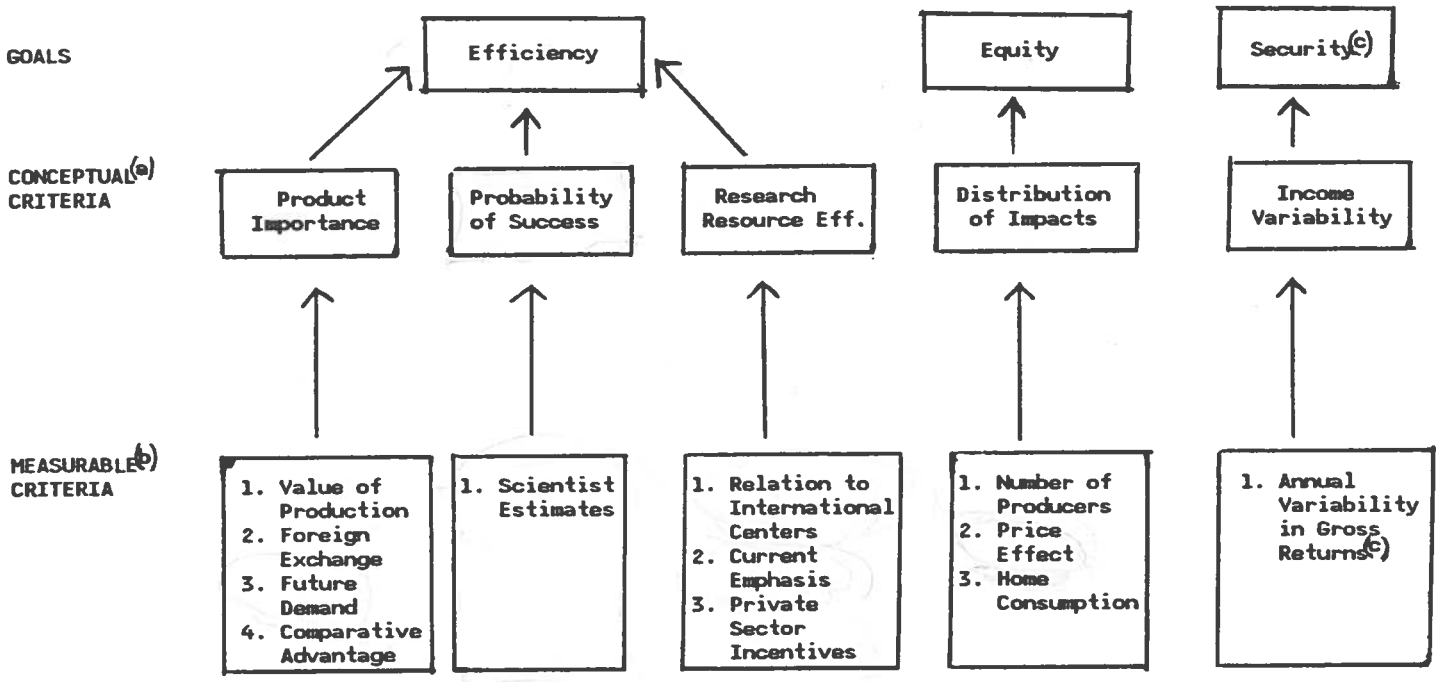
Data Collection and Model Implementation

Information used in the analysis included both quantitative data on value of production, number of farms, value of exports and imports, person-years devoted to research on different commodities, and the number of calories and grams of protein per day in the diet (for the Dominican Republic and Ecuador studies); as well as qualitative or subjective information on such factors as probability of success, private sector incentives, and severity of research problems. Furthermore, weights had to be elicited from decision makers to place relative emphasis on the various criteria.

Step 1. Develop Commodity and Research Area Lists -- The first step was to determine the list of commodities to consider and the list of research areas. In the Dominican Republic, information was collected on 74 commodities. In Ecuador, an initial list of 109 commodities on which INIAP was conducting research was discussed. Through decisions to eliminate some and to group others this list was reduced to 44 commodities for the analysis. These decisions were made by the Technical Director for Research. In Uruguay, a smaller list of commodities was reduced to 21 commodities or commodity groups. These decisions were made in consultation with the National Research and Extension Directors. The list of research program areas contained nine areas in the Dominican Republic, 16 in Ecuador, and 16 in Uruguay.

Step 2. Collect Quantitative and Qualitative Data on Chosen Criteria -- Information on quantitative criteria were gathered from local and FAO secondary data sources, and one table was constructed for each criterion. Commodities were ranked for each criterion. Information needed for the qualitative criteria as well as the weights to place on criteria were obtained through interviews with scientists and administrators at both the national and regional experiment stations. In Ecuador and Uruguay, substantial attention was devoted to identifying the appropriate respondents to each question, as this is a crucial aspect of the procedure. In Ecuador, those interviewed were notified one week before the interviews, and 72 people were interviewed by the Planning Director of INIAP and

FIGURE 1. CONCEPTUAL ELEMENTS IN THE WEIGHTED CRITERIA MODEL FOR RANKING RESEARCH PRIORITIES BY COMMODITY



Notes:

(a) In future studies, an additional conceptural criteria under the security goal might be 'health'.

(b) Nutritional criteria such as grams of protein or kilocalories could be included as additional measures of Distributional impacts.

(c) Not used in Dominican Republic, Ecuador, and Uruguay studies.

his assistant. In Uruguay, the directors of all the regional stations were called into CIIAB headquarters for a meeting to discuss the study, and this was followed up by on-site interviews and meetings with scientists and directors at the regional experiment stations, as well as with economists in the Ministry of Agriculture. These interviews and meetings were conducted by a person assigned to work with the Director of CIIAB on the priority-setting study. In the Dominican Republic, a survey of scientists, extension workers, and administrators was conducted by the ISNAR consultant from the Instituto Superior de Agricultura, who visited the various experiment stations. Less care was taken in the Dominican Republic than in Ecuador and Uruguay to match the questions pertaining to individual criteria to particular individuals. This probably reduced the usefulness of the responses, because those most familiar with the probability of research success, for example, may not be the same as those most familiar with comparative advantage.

Step 3. Elicit Weights on Criteria -- Relative weights to place on the different criteria were obtained from national and regional research system administrators. In Ecuador, 34 people were used to determine the weights. These weights were established separately for the commodity and the research area criteria. In Uruguay, fewer people (seven system and station directors) were used to determine the weights, and more attention was devoted to grouping the criteria pertaining to particular goals. A Delphi procedure was used in which the seven directors were shown the average of the group and provided with an opportunity to adjust their weight.

Step 4. Derive Rankings by Commodity and By Research Area -- Once the basic information was collected and organized into a series of tables, one procedure was followed to arrive at a final ranking of research priorities by commodity. A second procedure resulted in lists of priorities by research area. In the Dominican Republic, most of the calculations were made by hand. In Ecuador and Uruguay, microcomputer spreadsheet programs were used to assist with the calculations and to conduct sensitivity analysis.

The steps in the procedure for ranking research priorities by commodity and research area are summarized below and are illustrated with a simple example in Appendix 1. Briefly, the steps for ranking commodities were:

a) The commodities were ranked for each criterion for which quantitative data were available.
b) These rankings were multiplied by the weights assigned to each criterion and then the weighted criteria were added across to arrive at one sub-ranking for the quantitative criteria.
c) Each commodity was given a high, low, or none designation for each qualitative (subjective) criterion. The response which implied a need for greater research priority was assigned the number 2, the intermediate response was assigned 1, and the response which implied lower research priority was assigned 0. Therefore, each commodity received a 2, 1, or 0 for each criterion.
d) The weights assigned to each qualitative criterion were then multiplied by these numbers, and the results were added across all criteria to arrive at a subtotal for each commodity. These subtotals were ranked from highest to lowest to provide a second sub-ranking.
e) The sub-rankings for the quantitative and qualitative criteria were then given their corresponding weights and added together to arrive at a final ranking by commodity. The steps for ranking research priorities by research area were the same as steps (c) and (d) above because the criteria were all qualitative.

Step 5. Analysis and Interpretation of Results -- In the Dominican Republic, the results of this weighted criteria analysis were used to determine a small set of commodities and

research areas with the highest priority. Further assessment was then made of human, physical, administrative, and other resources needed to structure research programs focused on these commodities and research topics. In Ecuador and Uruguay, the prioritized list of commodities was split into a high-priority group, an intermediate-priority group, and a low-priority group. Research area priorities were identified for each region of the country. A more detailed analysis was then made of the human, physical, and other resources needed to support the high and intermediate priorities.

In summary, five major steps were involved in operationalizing the weighted criteria models. A complete set of results for each study included more than 20 tables and are not reproduced here. However, the final rankings for commodities and for research areas are shown in Tables 1 and 2 in Appendix 2. In the Dominican Republic, a team of consultants followed up the initial priority-setting exercise with additional analysis and discussions at the experiment station level and eventually recommended the establishment of five national commodity programs (rice, corn/sorghum, beans, coffee, and livestock) and one additional major research program (natural resources). In Ecuador, the prioritized lists were widely distributed and discussed in the Ministry of Agriculture, the Board of FEDIA, the Commission on Science and Technology, and in AID. There was concern in Ecuador with the weights placed on the individual criteria and, therefore, additional sensitivity analysis was conducted by the Planning Office of the Ministry. There seemed to be a recognition in Ecuador that priority setting with a weighted criteria model is an iterative process and that much of the model's value stems from the discussion of criteria among the decision makers and from the sensitivity analysis. The high-priority list of commodities in Ecuador included the ten highest-priority commodities listed in Table 2b. A project paper has been written for AID which recommends funding for FEDIA for three commodities (coffee, soft corn for the Sierra, and dairy). Coffee and soft corn were the number 2 and 3 ranked priorities in the weighted criteria model, and dairy was number 9, although it was the top-ranked livestock commodity.

In Uruguay, the results from the first run with the model were discussed with the research directors. The directors made small changes to the weights placed on criteria, and the model was rerun, resulting in the prioritized list in Appendix 2. Personnel in CIAAB are currently undertaking additional sensitivity analysis and, with the assistance of ISNAR, are developing a plan for implementation.

An Assessment of the Weighted Criteria Models Used in the Dominican Republic, Ecuador, and Uruguay

The Dominican Republic, Ecuador, and Uruguay studies were perhaps the first major attempts to implement weighted criteria models with weights explicitly elicited from decision makers in NARS in less-developed countries. A number of strengths and weaknesses in the procedures were identified during the analyses. Some of the weaknesses were corrected from one study to the next, some can be corrected in future studies, and others are inherent in the approach.

The first strength, mentioned earlier, is the ability of the procedure to systematically incorporate both quantitative and qualitative information related to a set of multiple goals and criteria in order to prioritize a long list of commodities and research areas in a relatively short period of time. Second, the procedure proved relatively easy for both research administrators and the local analysts to understand, with the exception of the Dominican Republic, where the research administrators were not directly involved.[7] Third, the analysis, as applied in Ecuador and Uruguay with the direct involvement of research system administrators at various stages, forced those decision makers to

consciously identify and trade off goals and criteria. Fourth, the use of spreadsheet programs in Ecuador and Uruguay facilitated sensitivity analysis after the initial set of priorities was determined. Fifth, the procedure provided a relatively objective assessment of priorities because individuals were not allowed to rank commodities or research areas directly, but had to weight criteria.

The first weakness inherent in ex ante research priority setting, and thus in the procedure, is that there is a large amount of subjectiveness. Although the approach is less subjective than unstructured judgment, there is subjectiveness in the responses to questions related to some of the criteria and also in the weights placed by decision makers on the criteria. Second, it proved difficult to specify independent criteria with no overlap. Third, while the procedure required less time than an expected economic surplus analysis by commodity, it required more time than asking respondents to directly rank commodities and research areas. In Ecuador, the consultant worked with personnel in INIAP and FEDIA for one week at the start of the analysis to determine goals and criteria, to arrive at a list of commodities and research areas, to list secondary data needs, to formulate questions to be asked of administrators and scientists, to decide who should be asked particular questions, and to explain the procedure itself, including the spreadsheet program. The required information was collected over the following month and the consultant returned and worked with the Planning Director in INIAP for one week to conduct the analysis and write up the results. Revisions to the initial draft of the report were then made over the following weeks. A similar procedure to the one followed in Ecuador was used in Uruguay, although more time was spent discussing the wording of questions to be asked of scientists. Furthermore, in Uruguay more care was taken to match the criteria with the goals.

Certain of the criteria will always be difficult to explain to the interviewees. The criterion on comparative advantage is difficult for some respondents because of a lack of knowledge about neighboring countries. If sufficient data, time, and resources are available, this criterion may be measured more precisely using comparative advantage or domestic resource cost procedures suggested by Longmire and Winkelmann. Another difficult criterion to estimate is the potential future demand for the product. The respondents in Ecuador were asked to consider how the demands for different foods would change as income and population grow. Many of them had a hard time conceiving that the total or per capita demand for certain foods could actually decline as income grew. In Uruguay, the comparative advantage and future demand questions were answered by a small group of economists from the ministries of agriculture and trade. In the Ecuador study, more attention was devoted to assessing the most appropriate people for answering different questions than was the case in the Dominican Republic. However, some criticism surfaced about the weights placed on criteria. In Uruguay, decision makers were given the opportunity to change their weights after viewing the initial results. This was very useful because it demonstrated the implications of placing different weights on the various goals and criteria.

Computer spreadsheet programs were a major help in Ecuador and Uruguay. Additional work needs to be devoted to developing a more menu-driven program, but the people in the planning office of INIAP were able to use the SuperCalc® program without too much difficulty, despite a lack of previous experience. The analyst in Uruguay was very familiar with Lotus® , which proved most helpful.

It became clear from working in all three countries that it is preferable to work directly with the final decision makers or their designees. In the Dominican Republic, the study was conducted by a very competent set of consultants from the local agricultural university, but the procedure was not institutionalized to allow for additional sensitivity analysis or future priority-setting efforts. In Ecuador, and especially in Uruguay, the

decision makers were directly involved, conducted sensitivity analyses, and were able to assess why certain commodities or research areas received high priority as a result of the analyses. In both Ecuador and Uruguay, they have a basic understanding of the strengths and weaknesses of the procedure and therefore can explain their subsequent decisions to groups who might disagree with the priorities they establish.

The contrast between the Dominican Republic and the Uruguay studies illustrates a very important point. No matter which technique is used to structure the analysis, priority-setting exercises must integrate the decision makers (users) into the process. Priority-setting procedures must be institutionalized, the results of initial analysis discussed thoroughly with decision makers, and sensitivity analysis conducted along the lines suggested by that discussion.[8] Technological change generates a surplus which can be appropriated by different sectors or groups within the economy. Who benefits depends in part on the commodities selected for research and the types of technologies generated. One of the purposes of institutionalizing a formal priority-setting procedure is to help mediate conflicts that may arise (for example between producer groups and consumers) as a result of research-induced improved technologies.

Other issues arose during the analyses. First, the initial grouping and elimination of certain commodities and research areas before the analysis is an important step, but one which must be taken with careful consideration of possible complementarities in research on particular products or types of research. Second, some of the commodities, such as forages, are inputs into other commodities such as milk. Consequently, these commodities may have to be considered as groups because it is the value-added and not the gross value of output that is relevant when one commodity requires other commodities as inputs and when criteria such as value of production are used. This was an issue in Uruguay, where livestock are quite important. Third, little attention was devoted in any of the studies to defining appropriate criteria for the increased income stability goal. Future studies, if this be an identified goal, should define risk criteria.

In summary, the weighted criteria model, as applied in Ecuador and Uruguay, which had the advantage of building on lessons learned in the Dominican Republic, appears to have been a useful priority-setting tool. It has its greatest advantage in situations in which there are multiple goals to consider, a relatively major reassessment of priorities is contemplated, and the list of commodities and research areas to consider is large. Weighted criteria models described in this paper were applied in small countries with limited resources, but with direct involvement (except in the Dominican Republic) of the major decision makers. These models may be most useful in the small country situation, where decision makers are more likely to be involved in the priority-setting *process* and are not just using tables of results. Perhaps in larger systems where decision making is more decentralized, the weighted criteria model can be applied at the regional level before refining research priorities at the national level.

Another factor that can be important in large systems is the complementarity between research and education. The larger the system, the closer the linkages tend to be between universities and the research system. Where universities are important for agricultural research, an additional criterion may be needed to place value on the educational benefits of certain types of research.

There are several additional implications with respect to how weighted criteria models relate to alternative priority-setting methods, particularly the expected economic surplus approach. Before exploring these relationships, key aspects of the surplus approach are described, based on an application in Peru.

IV. THE USE OF EXPECTED ECONOMIC SURPLUS ANALYSIS IN PERU

In 1985, an expected economic surplus analysis was conducted of the five major commodity research and extension (R & E) programs in Peru. These R & E programs for rice, corn, small grains, potatoes, and beans were begun in 1981 and the benefits were just beginning to flow at the time of the analysis. Consequently, the study was basically an evaluation of future benefits and previous costs. The intent was not to prioritize among the five commodity programs but to estimate rates of return to the R & E investment and to calculate the distribution of benefits between producers and consumers to provide information to the new government about those programs. However, the same basic procedure could be used for priority setting. In fact, Davis, Oram, and Ryan of ACIAR and IFPRI have recently developed an expected economic surplus model to assist ACIAR in establishing its research funding priorities.[9] The following assessment of the Peru study provides a useful perspective on the potential application of this approach in a developing country context.

The procedures briefly summarized here are described in more detail in Norton, Ganoza, and Pomareda. The first step involved developing questionnaires to be used in interviews with researchers and extension workers. Forty-five experiment station researchers were interviewed to obtain their projections of the most likely yield or cost changes due to particular research projects, probabilities of success, and time lags for the release of new technologies. Forty extension workers were interviewed to obtain their projections of the timing and geographical spread of new technologies and estimates of the depreciation of previous technologies. Research and extension workers were asked about additional inputs needed to use the improved methods, possible expansion of area cultivated and/or replacement of existing crops, and about the spread of new technologies with and without extension.

The benefits of agricultural R & E were quantified using an expected economic surplus criterion. Changes in producer and consumer surplus resulting from rightward shifts in the supply curve that had occurred or were projected to occur due to technological change were calculated. Separate analyses were conducted for each commodity and different benefit formulas were used depending on the situation for each commodity with respect to imports or exports, marketable surplus, shifts in demand over time due to population and income, and government pricing policies. Internal rates of return to research were calculated and the distribution of benefits to producers and consumers was assessed. Research cost data for the analysis came from INIPA records. Consumer and producer surplus analysis requires estimates of the price responsiveness (elasticities) of supply and demand. Published expenditure elasticities were used to approximate income elasticities and to calculate price elasticity of demand estimates. The income elasticities were needed to help assess shifts in demand over time. Supply elasticity estimates were not available, and alternative assumptions were used in the analysis. Calculations were performed using a microcomputer spreadsheet program (*SuperCalc*^{R}), and a substantial amount of sensitivity analysis was performed. Summarized results from that study are shown in Tables 3 and 4 of Appendix 2.

An Assessment of the Expected Economic Surplus Procedure Used in Peru

The expected economic surplus approach used in Peru proved particularly useful for capturing the effects of alternative pricing policies on both the total and the distribution of research benefits. Thirty-five cases were included in the spreadsheet program to allow for different demand, trade, policy, and other assumptions. The study was conducted over a four-month period of time. Because a different spreadsheet analysis must be completed for each commodity and because of the detailed information required on factors such as income and price elasticities, it would be difficult to apply the procedure

used in Peru to a long list of commodities. It may make sense in future studies, however, to narrow down the list of alternatives using a weighted criteria procedure to a small set (10-20) and then use the expected economic surplus approach to prioritize those alternatives using the weights derived from the first step to weight the efficiency and distribution goals.

It is difficult to use the expected economic surplus procedure for ranking research areas because of the problem of applying it to certain areas such as socio-economics, to relatively basic research, and to systems or interdisciplinary research. However, it can be used to estimate the economic returns of many other types of research such as plant breeding, weed and disease control, etc.

The expected economic surplus approach does require a higher level of economic training on the part of the local analyst than does the weighted criteria approach. In addition, the procedure, as currently implemented, appears to be more of a black box for decision makers. It was easier to explain the logic of the weighted criteria procedure to administrators than it was the expected economic surplus procedure. Finally, the expected economic surplus procedure cannot readily incorporate certain criteria, such as private-sector incentives, to the conduct of research.

V. IMPLICATIONS FOR DEVELOPMENT OF IMPROVED RESEARCH PRIORITY-SETTING PROCEDURES

The transfer of new technologies depends on how suitable those technologies are to local conditions. The same is true for institutional innovations such as improved research priority-setting procedures. Not only are multiple goals and criteria important in most strategic decision-making situations in NARS, but decisions of different levels of importance are made and differing amounts of time and resources are available for making those decisions. At times, research systems are substantially restructured. At other times, changes are made at the margin. In some countries, the basic research institutions (facilities and scientists) are available for research, but in others the institutions are much less developed. Consequently, there is a need for a flexible approach that can be tailored to the time frame, resources available, and the economic importance of the decision. Furthermore, priority-setting exercises such as those described above require additional follow-up activities of several types. Research projects must be defined, human resource decisions made, and programming completed for other aspects of the research activity.

When very few resources are available for the decision making process, the time frame is short, or the economic importance of a particular allocation decision is relatively small, a general set of guidelines provided to decision makers based on economic principles, may help sensitize decision makers to key research priority-setting issues. Binswanger and Ryan provided some guidelines in an article a few years ago. Norton and Ganoza (1986) developed a set of guidelines based on first applying the value of production criteria and then following this up with a set of questions which decision makers can ask themselves during annual research planning meetings. Particularly for project or more tactical decisions, such guidelines might prove useful because of their reduced time requirements for analysis and the higher level of uncertainty inherent in the potential success of individual projects.

As the importance of the decision increases and a more formal process is desired, the weighted criteria method may be helpful, particularly when the commodities or research areas to be considered are numerous and where research outputs are difficult to quantify. If the number of commodities to consider is small, the research outputs are relatively

easy to quantify, and additional time and resources are available, then the expected economic surplus approach mentioned earlier may be useful. With that approach, the economic rates of return to research on different commodities or research areas can be calculated and a more accurate projection made of the distribution of benefits between producers and consumers. Benefits also can be regionalized within a country and between countries by considering spillover effects as suggested by Davis, Oram, and Ryan[10].

It is important to recognize the direct relationship between the weighted criteria method and the expected economic surplus approach. Essentially, the expected economic surplus procedure explicitly assumes that the research goals are: raising the level of national income (efficiency) and equity (distribution). Therefore it captures most of the criteria mentioned in the weighted criteria discussion and removes the need to weight individual criteria. There remains a need to weight the efficiency and distributional goals, but the same procedure used in the weighted criteria model can be used to elicit weights for those goals. Within the set of distributional goals, weights can be applied to different regions and to producers versus consumers. If only the economic (internal) rate of return is used to rank commodities, then all the weight is implicitly placed on the efficiency goal.

Because the expected economic surplus approach subsumes a large array of variables into a manageable number of indicators, it allows for consistent and reproducible integration of both economic and scientific variables into the priority-setting decision process. These include:

a) Economic Variables:

- quantity of specific commodities produced and consumed
- commodity prices
- price responsiveness of supply and demand
- demand shifters (population, income)
- degree and nature of distortions due to price policies
- discount rate
- cost of research

b) Technical Variables[11]

- probability for success of each research program
- direct (output-enhancing or cost-reducing) effects of research over time (for example, expected yield gains from research)
- expected time rate of adoption and geographical spread of research results
- (inter-regional) spillover effects of research results

In summary, general guidelines, weighted criteria models, expected economic surplus models, and others have their own comparative advantage and can also be used together. Therefore, one logical solution to meeting the needs for priority-setting mechanisms in NARS is to develop a flexible menu-driven interactive computer program that can assist the analyst in selecting and employing alternative procedures. The procedure selected would depend on the adequacy of the data, resources and time available, and economic importance of the decision. This program could then be used as part of an institutionalized priority-setting and research management process.

VI. CONCLUSIONS

Potential exists for developing a formalized flexible procedure for use by NARS managers in research priority setting. This procedure can build on existing weighted criteria and expected economic surplus models, but additional refinements are needed. NARS administrators in Ecuador and Uruguay were very receptive to the structured weighted criteria model. Research administrators in the Dominican Republic, who were not involved in the model development, were apparently less receptive, which points out the need to institutionalize the model in the research agency during the model's initial use in a particular country. Benefits of structured priority-setting procedures are generated as much by the process of decision makers considering criteria and weights on goals as they are by the final results.

Key elements to be included in weighted criteria priority-setting procedures include (1) eliciting the major development goals to which the research system is expected to contribute, (2) defining a set of criteria for commodity and research area selection, (3) suggesting a set of measures to assist in ranking commodities or research areas for each criteria, (4) specifying secondary and primary information needs resulting from the measures, (5) providing questionnaires, and (6) defining the weighting procedure for aggregating across criteria to arrive at a final set of research priorities. If the initial number of alternatives is small, or is narrowed down after applying the weighted criteria model, the potential exists for employing an expected economic surplus analysis procedure. In that case, consumer and producer surplus would provide the measures of several of the criteria, but weights would still need to be applied to the efficiency and distributional goals. Potential also exists for placing weights on those goals and also placing weights on additional goals and criteria such as income stability, non-duplication of private-sector research, the educational benefits of research, or environmental sustainability.

It is important to remember that all priority-setting procedures are subjective. Also, different procedures require different amounts of time (analyst and decision makers), resources, and information. Any improvements in the procedures currently employed in NARS must more than pay for themselves through improved agricultural productivity as a result of improved allocations of research money. Recent methodological improvements in priority-setting procedures and enhanced computer capabilities increase the chances of making cost-effective changes in priority-setting procedures in NARS.

Footnotes

1) See Ruttan for a discussion of several of these studies.

2) Rules of thumb are sometimes used, such as the congruence approach, where funds are allocated across research programs in proportion to the value of agricultural production in each commodity. See Salmon for a discussion and application of this approach.

3) Changes often result as well from the introduction of foreign-assisted research projects.

4) It takes time for agricultural research to yield new results. For example, Pardey reports an average research gestation lag for the U.S. state agricultural experiment stations during the early 1970s of around three to four years.

5) Additional discussion of these methods can be found in Shumway, Ruttan, Schuh and Tollini, Parton *et al*, Anderson and Parton, Scobie, and Norton and Davis.

6) See Havlicek and Norton for a summary of several of these procedures. Caution is needed when applying quantitative procedures to research project selection because scientists are often the best judge of the appropriate projects within a given research area.

7) The Dominican Republic was in the process of restructuring its agricultural research system at the time of the priority-setting study, and the newly created agency (IDEA) was without a director.

8) The need for discussion and sensitivity analysis is evident in the list of research priorities by commodity shown in Table 1a of Appendix 2. That list includes some surprises compared with a ranking based on value of production.

9) The expected economic surplus approach, as described by Davis, Oram, and Ryan, is particularly useful for international agencies because of its emphasis on spillovers across countries.

10) ACIAR and ISNAR are currently refining the Davis, Oram, and Ryan expected economic surplus procedure to incorporate regional spillovers within countries.

11) Clearly, the economic-technical dichotomy presented here is principally for expository purposes. "Technical" variables, such as the expected rate of adoption and spillover effects, are responsive to both technical and economic forces. Nevertheless, the dichotomy is useful when thinking about the principal sources of data. Many of the economic variables can be obtained from secondary sources, while some of the technical variables require direct input from scientists and program leaders. In the absence of hard data, the sensitivity of the results can be tested against a reasonable range of parameter estimates.

References

Alston, J. M., G. W. Edwards, and J. W. Freebairn. Market Distortions and Benefits from Research. Department of Agriculture and Rural Affairs in Victoria, and La Trobe University, March 1987, Mimeo.

Anderson, J. R., and K. A. Parton. "Technologies for Guiding the Allocation of Resources Among Rural Research Projects: State of the Art." *Promethus*, 1(1983): 180-201.

Araji, A.A., R. J. Sim, and R. L. Gardner. "Returns to Agricultural Research and Extension Programs: An Ex Ante Approach." *Amer. J. Agr. Econ.* 60(1978): 964-8.

Binswanger, H. P. and J. G. Ryan. "Efficiency and Equity Issues in Ex-Ante Allocation of Research Resources." *Indian J. of Agr. Econ.*, 32(1977): 217-31.

Centro de Investigacion Agricola "Alberto Boerger" (CIAAB). Identificacion y Seleccion De Prioridades de Investigacion Agropecuaria en el Uruguay. Report prepared for CIAAB by G. Ferreira, G. Norton, and C. Valverde, May 1987.

Consultative Group on International Agricultural Research (CGIAR). Technical Advisory Committee. *TAC Review of CGIAR Priorities and Future Strategies.* TAC Secretariat, Food and Agriculture Organization of the United Nations, August 1985.

Davis, J.S., P.A. Oram, and J.G. Ryan. "Assessing Aggregate Agricultural research Priorities: An International Perspective." Australian Centre for International Agricultural Research (ACIAR) and the International Food Policy Research Institute (IFPRI), Draft, August, 1986.

Edwards, G. W., and J. W. Freebairn. *Measuring a Country's Gains From Research: Theory and Application to Rural Research In Australia.* A Report to the Commonwealth Council for Rural Research and Extension. Canberra: Australian Government Publishing Service, 1981.

Edwards, G. W., and J.W. Freebairn. "The Gains From Research into Tradeable Commodities." *Amer. J. Agr. Econ.* 66(1984): 41-49.

Espinosa, P., G. Norton, and H.D. Gross. Identificacion Y Seleccion De Prioridades De Investigacion Agropecuaria en el Ecuador, Instituto Nacional de Investigacion Agropecuaria (INIAP), Draft, October 1986.

Fishel, W.L. "The Minnesota Agricultural Research Resource Allocation System and Experiment." *Resource Allocation in Agricultural Research*, ed. W.L. Fishel. Minneapolis, Minnesota, University of Minnesota Press, 1971.

Havlicek, J. G., and G. W. Norton. A Review of Research Project Evaluation and Selection Methods: A Report to BARD. Staff Paper SP-13-81, Department of Agricultural Economics, Virginia Polytechnic Institute and State University, November 1981.

Instituto Superior de Agricultura (ISA). Contenido Tecnico de la Investigacion del Instituto Dominicano de Investigaciones Agropecuarias. Report prepared for

ISNAR in the Dominican Republic by W. Moscoso, A. Coutu, D. Bandy, and G. W. Norton, June 1986.

Longmire, J., and D. Winkelmann. Research Resource Allocation and Comparative Advantage. CIMMYT paper presented at the XIX Congress of International Agricultural Economics Association, Malaga, Spain, August 1985.

Mahlstede, J.P. "Long-Range Planning at the Iowa Agricultural and Home Economics Experimental Station." *Resource Allocation in Agricultural Research*, ed. W.L. Fishel. Minneapolis, Minnesota, University of Minnesota Press, 1971.

Norton, G.W., and J.S. Davis. "Evaluating Returns to Agricultural Research: A Review". *Amer. J. of Agr. Econ.* 63:(1981): 685-699.

Norton, G.W., and V.G. Ganoza. The Benefits of Agricultural Research and Extension in Peru, paper prepared for INIPA and for USAID, Lima, Peru, June 1985.

Norton, G.W., and V.G. Ganoza. Guidelines for Allocations of Resources to Agricultural Research and Extension in Peru, paper prepared for INIPA and for USAID, Lima, Peru, February 1986.

Norton, G.W., V.G. Ganoza, and C. Pomareda. "Potential Benefits for Agricultural Research and Extension in Peru", *Amer. J. Agr. Econ.* 69(1987): 247-257.

Pardey, P.G. The Agricultural Knowledge Production Function: An Empirical Look. Paper presented to the National Symposium on Evaluating Agricultural Research Productivity, Atlanta, Georgia, January 1987.

Parton, K.A., J. R. Anderson, and J. P. Makeham. *Evaluation Methods for Australian Wool Production Research.* Agricultural Economics Bulletin No. 29. Armidale: University of New England, 1984.

Paulsen, A., and D. R. Kaldor. "Evaluation and Planning of Research in the Experiment Station." *Amer. J. Agr. Econ.* 50(1968): 114962.

Pinstrup-Andersen, P., and D. Franklin. "A Systems Approach to Agricultural Research Resource Allocation In Developing Countries." *Resource Allocation and Productivity in National and International Research*, ed. T.M. Arndt, D.G. Dalrymple, and V.W. Ruttan, Minneapolis, Minnesota: University of Minnesota Press, 1977.

Ramalho de Castro, J.P., and G. E. Schuh. "An Empirical Test of An Econometric Model for Establishing Research Priorities: A Brazil Case Study." *Resource Allocation and Productivity in National and International Research*, ed. T.M. Arndt, D.G. Dalrymple, and V.W. Ruttan. Minneapolis, Minnesota: University of Minnesota Press, 1977.

Russell, D. G. "Resource Allocation in Agricultural Research Using Socio-Economic Evaluation and Mathematical Models." *Canadian J. Agr. Econ.* 23(1977): 29-52.

Ruttan, V. W. *Agricultural Research Policy*, Baltimore, Johns Hopkins University Press, 1982.

Salmon, D.C. Congruence of Agricultural Research in Indonesia 1974-78, Economic Development Center Bulletin 83-1, University of Minnesota, St. Paul, 1983.

Scobie, G.M. Investment in Agricultural Research: Some Economic Principles, CIMMYT Working Paper, Mexico, 1984.

Shumway, C.R., and R.J. McCracken. "Use of Scoring Models in Evaluation Research Programs." *Amer. J. Agr. Econ.* 57(1975): 714-18.

Von Oppen, M., and J. G. Ryan. "Research Resource Allocation, Determining Regional Priorities." *Food Policy.* 10(1985): 253-264.

Williamson, J.C. "The Joint Department of Agriculture and State Experiment Stations' Study of Research Needs." *Resource Allocation in Agricultural Research*, ed. W.L. Fishel. Minneapolis, Minnesota: University of Minnesota Press, 1971.

Appendix 1

Simplified Hypothetical Example for Selecting Commodity Priorities

Step a. Fill in a table for each quantitative criterion and rank commodities in each table in order of importance.

Product Value	Foreign Exchange	Number of Farms	Calories	Protein
1. Coffee	1. Coffee	1. Plantain	1. Rice	1. Rice
2. Rice	2. Maize	2. Rice	2. Plantain	2. Maize
3. Plantain	3. Rice	3. Cassava	3. Cassava	3. Plantain
4. Cassava	4. Cassava	4. Coffee	4. Maize	4. Cassava
5. Maize	5. Plantain	5. Maize	5. Coffee	5. Coffee

Step b. Multiply the weights which have been assigned to each criterion (for example, 30, 10, 10, 5, 5) by the number in the ranking for each quantitative criterion and add across to arrive at a ranking for that group of criteria.

		Rank
Coffee	$(1 \times .3)+(1 \times .1)+(4 \times .1)+(5 \times .05)+(5 \times .05) = 1.3$	2
Rice	$(2 \times .3)+(3 \times .1)+(2 \times .1)+(1 \times .05)+(1 \times .05) = 1.2$	1
Plantain	$(3 \times .3)+(5 \times .1)+(1 \times .1)+(2 \times .05)+(3 \times .05) = 1.75$	3
Cassava	$(4 \times .3)+(4 \times .1)+(3 \times .1)+(3 \times .05)+(4 \times .05) = 2.25$	4
Maize	$(5 \times .3)+(2 \times .1)+(5 \times .1)+(4 \times .05)+(2 \times .05) = 2.5$	5

Step c. Fill in a table for each qualitative criterion, placing each commodity in a high, medium, or low category for each criterion. In each table, give a 2 to those commodities for which the criterion implies the greatest need for more research, and a 0 to those commodities for which the criterion implies the least need for research.

	Yield Gap	**Success Probability**	**Relation to Int. Ctrs**	**Current Emphasis**	**Private Incentive**
Coffee	2	1	0	1	0
Rice	1	2	2	2	1
Plantain	1	1	0	1	2
Cassava	0	0	2	0	2
Maize	0	2	2	1	1

	Comparative Advantage	**Price Effect**	**Home Consumption**	**Future Demand**
Coffee	2	2	0	1
Rice	1	1	1	1
Plantain	1	0	2	0
Cassava	0	0	2	0
Maize	1	2	1	2

Step d. Multiply the weights assigned to each of the qualitative criteria (for example, 4, 4, 4, 6, 4, 8, 2, 2, 6) by the number assigned each commodity (2, 1 or 0) for each criterion and add across to arrive at a ranking for the group of qualitative criteria.

Coffee	(2 X.04)+(1 X.04)+(0 X.04)+(1 X .06)+(0 X.04)+	
Rice	(1 X.04)+(2 X.04)+(2 X.04)+(2 X .06)+(1 X.04)+	
Plantain	(1 X.04)+(1 X.04)+(0 X.04)+(1 X .06)+(2 X.04)+	
Cassava	(0 X.04)+(0 X.04)+(2 X.04)+(0 X .06)+(2 X.04)+	
Maize	(0 X.04)+(2 X.04)+(2 X.04)+(1 X .06)+(1 X.04)+	
		Rank
Coffee	(2 X.08)+(2 X.02)+(0 X.02)+(1 X .06)=.44	3
Rice	(1 X.08)+(1 X.02)+(1 X.02)+(1 X .06)=.54	1
Plantain	(1 X.08)+(0 X.02)+(2 X.02)+(0 X .06)=.34	4
Cassava	(0 X.08)+(0 X.02)+(2 X.02)+(0 X .06)=.20	5
Maize	(1 X.08)+(2 X.02)+(1 X.02)+(2 X .06)=.52	2

Step e. Now there are two rankings (one for the group of quantitative criteria and one for the group of qualitative criteria). Weight these two rankings by the total weights assigned to their respective sets of criteria to arrive at a final ranking.

		Final Rank
Coffee	(2 X.6)+(3 X .4)=2.4	2
Rice	(1 X.6)+(1 X .4)=1	1
Plantain	(3 X.6)+(4 X .4)=3.4	3
Cassava	(4 X.6)+(5 X .4)=4.4	5
Maize	(5 X.6)+(2 X .4)=3.8	4

Step f. Divide the final ranking into 3 groups: those commodities with highest priority, those with lower priority, and those with the least priority. This is a very subjective step and depends on the resources available for research, but has proven to be a useful step.

Group 1	**Group 2**	**Group 3**
Rice	Plantain	Cassava
Coffee	Maize	

Steps for Implementing Procedure for Research Area Selection

Step a. Each criterion for research area selection is qualitative. Fill in a table for each criterion assigning a 2 to those research areas for which the criterion implies the greatest need for more research, a 1 to those for which the criterion implies some need for research, and a 0 to those for which the criterion implies little or no need for research. These tables should be constructed separately for each region in the country for certain criteria.

	Resource Abundance	Problem Importance	International Center Relations	Private Incentive	Current Programs
Plant Breeding	2	2	2	0	2
Cultural Practice (crops)	1	1	1	1	2
Plant Protection	1	2	1	0	2
Soil Fertility	2	1	1	1	2
Soil Conservation	2	2	1	1	1
Water Use Efficiency	1	2	0	1	0
Mechanization	0	1	0	0	0
Socio-economics	1	1	1	1	1
Technology Transfer	2	1	1	1	1
Seed Production	1	1	1	1	1
Post-harvest Technology	1	1	0	1	1
Agro-forestry	2	1	1	2	1
Animal Breeding	2	1	0	0	1
Animal Health	1	2	0	0	0
Animal Nutrition	2	2	1	0	2
Aquaculture	1	0	0	1	0

Step b. Assign weights (out of a total of 100) to each criterion (for example, .35, .35, .1, .1, .1), multiply by the numbers in Step 1, and sum across to get a single ranking.

		Rank
Plant Breeding	(2 X .35) + (2 X .35) + (2 X .1) + (0 X .1) + (2 X .1) = 1.8	1
Cultural Practices (crops)	(1 X .35) + (1 X .35) + (1 X .1) + (1 X .1) + (2 X .1) = 1.1	10
Plant Protection	(1 X .35) + (2 X .35) + (1 X .1) + (0 X .1) + (2 X .1) = 1.35	6
Soil Fertility	(2 X .35) + (1 X .35) + (1 X .1) + (1 X .1) + (2 X .1) = 1.45	4
Soil Conservation	(2 X .35) + (2 X .35) + (1 X .1) + (1 X .1) + (1 X .1) = 1.7	2
Water Use Efficiency	(1 X .35) + (2 X .35) + (0 X .1) + (1 X .1) + (0 X .1) = 1.15	8
Mechanization	(0 X .35) + (1 X .35) + (0 X .1) + (0 X .1) + (0 x .1) = .35	16
Socio-economics	(1 X .35) + (1 X .35) + (1 X .1) + (1 X .1) + (1 X .1) = 1.0	12
Tech. Transfer	(2 X .35) + (1 X .35) + (1 X .1) + (1 X .1) + (1 X .1) = 1.35	6
Seed Production	(1 X .35) + (1 X .35) + (1 X .1) + (1 X .1) + (1 X .1) = 1.0	12
Post-harvest	(1 X .35) + (1 X .35) + (0 X .1) + (1 X .1) + (1 X .1) = .9	14
Agro-forestry	(2 X .35) + (1 X .35) + (1 X .1) + (2 X .1) + (1 X .1) = 1.45	4
Animal Breeding	(2 X .35) + (1 X .35) + (0 X .1) + (0 X .1) + (1 X .1) = 1.15	8
Animal Health	(1 X .35) + (2 X .35) + (0 X .1) + (0 X .1) + (0 X .1) = 1.05	11
Animal Nutrition	(2 X .35) + (2 X .35) + (1 X .1) + (0 X .1) + (2 X .1) = 1.7	2
Aquaculture	(1 X .35) + (0 X .35) + (0 X .1) + (1 X .1) + (0 X .1) = .45	15

Appendix 2 -- Results

Table 1a. Ranking of Research Priorities by Commodity from the Weighted-Criteria Model Applied in the Dominican Republic

Commodity	Rank	Commodity	Rank
Arroz (cascara)	1	Aguacate	47
Cafe (cerezo)	2	Lechuga	48
Leche	3	Limon Dulce	49
Frijol	4	Zapote	50
Carne de Res	5	Toronja	51
Maiz (grano)	6	Melon	52
Coco de Agua	7	Name	53
Tomate	8	Nispero	54
Cacao (grano)	9	Molondron	55
Huevos	10	Jagua	56
Naranja Dulce	11	Berenjena	57
Auyama	12	Repollo	58
Carbon Vegetal	13	Lechoza	59
Guandul	14	Rulo	60
Batata	15	Pepino	61
Lena Familiar	16	Zanahoria	62
Cana Azucar	17	Cabuya (Sisal)	63
Haba	18	Remolacha	64
Platano	19	Arveja	65
Carne de Aves	20	Jengibre	66
Naranja Agria	21	Ajonjoli	67
Carne de Cerdo	22	Higuereta	68
Algodon (rama)	23	Tayota	69
Fruto de Palma	24	Mapuey	70
Yuca	25	Bija	71
Mani (cascara)	26	Cajuil	72
Tabaco (rama)	27	Rabano	73
Carne Ovina/Caprin	28	Tamarindo	74
Ajo	29		
Guineo	30		
Yautia	31		
Limon Agrio	32		
Oregano	33		
Cera de Abejas	34		
Papa	35		
Aji	36		
Garbanzo	37		
Cebolla	38		
Miel de Abejas	39		
Cebollin	40		
Guanabana	41		
Lena Industrial	42		
Mango	43		
Pesca	44		
Otros Frijoles	45		
Pina	46		

Table 1b. Ranking of Research Priorities by Commodity from the Weighted-Criteria Model Applied in Ecuador

Commodity	Rank	Priority Level
Arroz	1	
Cafe	2	
Maiz Sierra	3	
Cebada	4	
Platano	5	High
Papa	6	
Banano	7	
Cacao	8	
Ganado de Leche	9	
Maiz Costs	10	
Trigo	11	
Fruitas Hoja Caduca	12	
Frejol	13	
Ganado de Carne	14	
Leguminosas and. Men	15	
Yuca	16	Medium
Fruitas Citricos	17	
Lenteja	18	
Leguminosas Costa	19	
Cereales Andinos	20	
Porcinos	21	
Fruitales Tropicales	22	
Cereales Menores	23	
Cultivos and Menores	24	
Mami	25	
Ovinos	26	
Fruitales Subtropical	27	
Hort. de Clima Frio	28	
Hort. Tropical	29	
Aves	30	Low
Caprinos	31	
Chontaduro	32	
Soya	33	
Palma Africana	34	
Sorgo	35	
Algodon	36	
Especies Menores	37	
Oleaginosas Menores	38	
Cana	39	
Hort. Subtropical	40	None
Tabaco	41	
Flores	42	
Jojoba	43	
Te	44	

Table 1c. Ranking of Research Priorities by Commodity from the Weighted-Criteria Model Applied in Uruguay (Preliminary Results)

Commodity	Rank	Priority Level
Beef Cattle	1	
Wheat	2	High
Forages	3	
Dairy	4	
Citrus	5	
Potatoes	6	
Maize	7	
Sheep	8	
Rice	9	Medium
Other Fruits	10	
Grapes	11	
Sunflowers	12	
Soybeans	13	
Vegetables	14	
Sorghum	15	
Barley	16	
Tomatoes	17	
Swine	18	Low
Peanuts	19	
Linseed	20	
Grain legumes	21	
Frutilla	22	

Table 2a. Ranking Assigned to Research Areas by the Weighted-Criteria Model in the Dominican Republic

Research Area	Ranking
Natural Resources (soils, water, forests)	1
Plant Breeding, Cultural Practices, Crop Systems	2
Animal Nutrition and Management	3
Technology Transfer	4
Animal genetics and reproduction	5
Socioeconomics	6
Plant Protection	7
Post Harvest Technology	8
Mechanization	9

Table 2b. Ranking Assigned to Research Areas by the Weighted-Criteria Model in Ecuador.

Research Area	Aggregate Ranking	Ranking by Region										
		1	2	3	4	5	6	7	8	9	10	11
Cultural Practices (crops)	7	1	8	6	8	9	9	10	8	8	12	6
Agro-Forestry	2	2	2	2	1	3	3	4	3	2	7	7
Animal Nutrition	3	3	3	7	11	5	5	2	4	10	2	3
Soil Conservation	4	4	4	3	3	6	12	6	5	4	9	9
Socio-economics	10	5	6	8	4	7	6	15	11	5	3	10
Technology Transfer	4	6	7	4	5	8	7	7	6	6	4	4
Seed Production	4	7	5	5	6	10	8	3	7	7	5	5
Plant Breeding	1	8	1	1	7	1	1	1	1	1	1	1
Soil Fertility	7	9	9	9	9	2	2	11	2	9	6	2
Post-Harvest technology	13	10	10	10	10	15	10	12	13	14	13	13
Plant Protection	9	11	12	12	2	4	4	5	9	3	8	8
Water Use	11	12	14	14	13	11	13	8	14	12	10	11
Animal Health	16	13	16	16	11	16	15	16	16	16	16	16
Livestock Breeding & Management	14	14	13	13	12	13	11	14	10	11	15	15
Aquaculture	11	15	15	15	14	14	14	9	12	13	11	12
Mechanization	15	16	11	11	16	12	16	13	15	15	14	14

Region 1 = Tropical and dry Subtropical
Region 2 = Occidental de Pichincha
Region 3 = Estacion Experimental Santo Domingo
Region 4 = Subtropico Seco-Loja
Region 5 = Provincia del Ovo
Region 6 = Estacion Experimental Portoviejo
Region 7 = Estacion Experimental Boliche
Region 8 = E. E. NAPO Payamino
Region 9 = E. E. Tropical Pichilingue
Region 10 = E. E.Santa Catalina
Region 11 = E. E. Chuquipata

Table 2c. Ranking Assigned to Research Areas by the Weighted-Criteria Model in Uruguay

Research Area	Aggregate Ranking	Ranking by Region 1	2	3	4	5
Plant Protection	1	7	7	1	10	1
Agroclimatology	2	11	9	2	4	5
Plant Breeding	3	12	1	8	1	6
Livestock Management	4	2	5	11	13	7
Livestock Nutrition	5	9	4	13	11	8
Production Systems	6	8	3	10	7	12
Pasture Management	7	4	6	15	14	2
Soil Management	8	13	2	4	8	3
Animal Health	9	3	11	16	16	4
Plant Nutrition & Physiology	10	14	13	5	9	9
Cultural Practices	11	5	8	3	6	11
Socioeconomics	12	10	14	7	3	13
Animal Reproduction	13	1	10	12	12	10
Evaluation of Products	14	15	16	9	5	16
Animal Improvement	15	6	12	14	15	14
Post-Harvest Tech.	16	16	15	6	2	15

Region 1 = El Norte
Region 2 = La Estanzuela
Region 3 = Salto
Region 4 = Las Brujas
Region 5 = Este

Table 3. Summary of Internal Rates of Return to INIPA Research and Extension[a]

	RICE[b]	CORN	WHEAT	POTATOES	BEANS	AGGREGATE[c]
Research Investment from 1981 to 1986 and Extension from *1981 to 1990*						
Free Trade						
Pivotal Shift in Supply Curve	.17	.10	.18			.17
Parallel Shift in Supply Curve	.35	.23	.28			.33
No Trade						
Pivotal Shift in Supply Curve	.18			.22	.14	
Parallel Shift in Supply Curve	.37			.42	.24	
Research Investment from 1981 to 1992 and Extension from *1981 to 1996*						
Free Trade						
Pivotal Shift in Supply Curve	.30	.20	.28			.25
Parallel Shift in Supply Curve	.44	.31	.36			.38
No Trade						
Pivotal Shift in Supply Curve				.22	.14	
Parallel Shift in Supply Curve				.42	.24	

(a) Assumes no expansion of cultivated area.

(b) When expansion in cultivated area of 1% per year was assumed, these rates more than doubled. For example, the return to research and extension on rice for the 1981 to 1986 research investment and 1981 to 1990 extension investment changed from .17 to .48.

(c) Neither Free Trade nor No Trade.

Table 4. Percent Distribution of Total Net Economic Surplus to INIPA Research and Extension for No Trade Scenarios[a]

		Pivotal Supply Shift		Parallel Supply Shift	
		Consumer Gain	Producer Gain	Consumer Gain	Producer Gain
Rice	n = -.76	83	17		
	n = -.39	105	-5	52	48
	n = -.27	115	-15		
Potatoes	n = -.64	72	28		
	n = -.34	88	12	44	56
	n = -.24	95	5		
Beans	n = -.61	74	26		
	n = -.31	91	9	46	54
	n = -.21	99	1		

[a]All benefits accrue to producers for the trade scenario for rice, corn, and wheat when the price elasticity of demand is perfectly elastic.

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